VIRGINIA DEPARTMENT OF MINES, MINERALS & ENERGY
DIVISION OF MINES

SURFACE BLASTER
CERTIFICATION STUDY GUIDE

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SURFACE BLASTER STUDY GUIDE
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INTRODUCTION

INTRODUCTION

This guide was written to assist in providing the knowledge and safety practices necessary to perform the duties of a surface blaster. A blaster must have a thorough knowledge of the theory, storage, handling, transportation and use of explosives.

This guide will also assist in the conduct of good blasting operations, protection of health and safety of miners, protection of the surrounding community and the environment.

A miner shall have one (1) year of surface coal mine related blasting experience to certify as a surface blaster. This experience shall include duties that consist of the storage, handling, transportation and use of explosives. A surface blaster is a two-part certification that consists of a Division of Mines and a Division of Mined Land Reclamation component. A person must satisfy the requirements of both divisions in order to be certified as a coal mine surface blaster.

The use of explosives in the mining industry continues to present a potentially serious risk of injury and death of miners.

The prevention of explosive accidents depend, to a large extent, on two factors: (1) the knowledge and experience of persons responsible for the use of explosives and (2) well defined safety precautions to guide mine operators and miners in the safe conduct of blasting operations.

The prevention of explosive accidents depends on careful planning and faithful observance of proper blasting practices. The slightest abuse or misdirection of explosives may either kill or cause serious injury to miners and the public.

Two general statements should be acknowledged and understood about the safety and use of explosives:

(1) A blaster's most important responsibility is safety;
(2) The safety of every blasting operation depends on it's people.

A surface blaster must possess the proper attitude to become a safe and efficient blaster. The safety of every blasting operation is also dependent upon the attitude, knowledge, training, and experience of other miners who handle and use explosives.

Miners designated to handle explosives must have intelligence, common sense, training in the use of explosives, and they must know what is and is not safe.

Explosive safety is a habit that can only be developed through constant training and repletion of safe working habits.

Explosive safety is developed through the proper individual attitude and the proper training to transport, store, handle and use of explosives in a safe manner.

Safety is the individual responsibility of every miner for their safety and the safety of other miners.

A surface blaster shall always obey State and Federal Laws and manufacturer instructions applicable to transporting, storing, handling, and using explosives.

The appropriate explosive manufacturer should be consulted in any situation when a blaster has any doubt or questions involving explosives.

UNIT II

EXPLOSIVE PRODUCTS

EXPLOSIVE PRODUCTS

HIGH EXPLOSIVES

An explosive is a chemical compound or mixture of compounds that undergoes a very rapid decomposition when initiated by heat, shock, friction, or a combination of these conditions. When detonated, explosives decompose very rapidly in a detonation which produces large amounts of heat and gases. The very hot gases produce extremely high pressures within the borehole. Those pressures cause the rock formations to be fragmented by overcoming the confining forces of the rock.

A high explosive is any product that can be detonated with a Number 8 cap test and reacts at a speed faster than the speed of sound through an explosive medium. All blasting explosive products are classified as high explosives if they are sensitive to the Number 8 blasting cap test. Products are classified as a high explosive when the speed of the detonation through the explosive medium is faster than the speed of sound. If the detonation reaction speed is slower than the speed of sound, the product is called a low explosive. Low explosives are seldom used in blasting today.

The main reacting ingredients in an explosive are fuels and oxidizers. Common fuels in commercial products include fuel oil, carbon, and aluminum. Common explosive sensitizers are nitroglycerin, nitrostarch, aluminum, TNT, and bulking agents for density control. The most common oxidizer is ammonium nitrate, even though sodium nitrate and calcium nitrate are sometimes used. Explosives also contain ingredients such as water, gums, thickeners, and agents in slurries such as flame retardant, absorbents, stabilizers, densifiers and gelatinizers.

Most ingredients of explosives are composed of the elements oxygen, nitrogen, hydrogen, and carbon. Metallic elements such as aluminum are sometimes added to an explosive product. Adding finely divided or flaked aluminum to explosives increase the energy output of explosives but at a cost increase. The common high-energy producing additives, which may be added to blasting agents and slurries, fall into two categories: explosives such as TNT and metals such as aluminum. Both of these mixtures release more energy and have higher densities then the standard mixture of ANFO and slurries. The increased energy output and higher densities must be weighed against the higher cost of these additives. These high-energy additives are commonly uneconomical except for specialty products such as primers and boosters.

The energy release of explosive products are maximized when a product has sufficient oxygen to oxidize all the fuels but no excess oxygen to react and form nitrogen oxide. Improper oxygen balance in explosives are inefficient in heat energy production and also produce poisonous gases in the form of carbon monoxide and oxides of nitrogen.

Products used in surface blasting are divided into three categories: nitroglycerin-based high explosives, dry blasting agents and slurries which may also be referred to as emulsions. The nitroglycerin-based explosives are the most sensitive commercial products used today excluding detonators. This sensitivity property offers an extra margin of dependability in boreholes but are more susceptible to accidental detonation. Nitroglycerin was the first high explosive and is the sensitizer used in several explosive products but is seldom, if ever, used alone in an explosive product.

The detonation of explosives produces four basic effects: (1) rock fragmentation, (2) rock displacement, (3) ground vibration, (4) air blast. The performance of an explosive depends upon the rate of energy release and how effectively the energy fragments and moves the material that is blasted. Both the explosive properties and properties of the material being blasted influence the effectiveness of an explosive.

BLASTING AGENTS

A blasting agent is any material or mixture consisting of a fuel and an oxidizer, intended for blasting, not otherwise classified as an explosive, provided that the finished product as mixed and packaged for shipment cannot be detonated by a number 8 blasting cap test as tested by the Bureau of Mines.

ANFO (ammonium nitrate-fuel oil) is the most common blasting agent. ANFO can be made cap sensitive by pulverizing the ammonium nitrate to a fine particle size, thus requiring the classification of an explosive.

ANFO accounts for over 80 percent of the domestic commercial explosives market and is the cheapest source of explosive energy available today. ANFO popularity has increased over the past forty (40) years because of economy and convenience. Lack of water resistance, low-product density and small borehole restrictions are the major limitations of ANFO. The most widely used ANFO product is an oxygen-balanced, free flowing mixture of about 94 percent ammonium nitrate prills and 6 percent of number 2 diesel fuel oil. Other ANFO product modifications are: (1) substances such as coal dust are used to replace the fuel oil (2) the ANFO prills are crushed (3) the product is packaged in a water resistant package for use in wet boreholes. Adding finely divided or flaked aluminum to ANFO will increase the energy output but at an increase in cost.

ANFO'S energy is optimized at oxygen balance with the 94.3% to 5.7% ratio. Excess fuel oil can seriously reduce sensitivity to initiation. Inadequate fuel oil causes an excess of harmful nitrogen-oxide fumes in the detonation gases. The amount of fuel oil also affects the energy velocity, sensitivity and fumes of ANFO and other similar products. ANFO with 6Z fuel oil produces the maximum energy and the highest detonation velocity while the sensitivity rapidly decreases above and below 6Z. Blasts of ANFO that produce orange-brown smoke, usually oxides of nitrogen, indicate the product has insufficient oil or water dissolved the ANFO while separating it from the oil. The amount of fume production depends to a large extent on the conditions under which the ANFO product is used.

The specific gravities of ANFO range from .5 to 1.15 with .8 to .85 being the most common range. The lighter gravities are used in easily fragmented rock or when a low powder factor is desirable. The density of an explosive is the major factor that affects the specific gravity of an explosive. Densities of explosives are compared to the standard of water which has a density of 1. if there is water in a borehole, an explosive with a density greater than 1 is required so that the explosive will sink. Dry ANFO is densified and packaged in waterproof containers for use in wet boreholes. The densification is necessary to enable the cartridges to sink in water. Most ANFO weighs about 54 pounds per cubic foot.

The detonation velocity of poured ANFO depends on the borehole diameter and degree of confinement in the shot. The critical diameter of pneumatically loaded ANFO is near 1 inch. ANFO use in boreholes less than 2 inches should be restricted to absolutely bone-dry conditions. The detonation velocity for ANFO increases as the diameter of the borehole increases. ANFO reaches its maximum velocity of 15,000 feet per second in a 10 inch diameter borehole. Increasing the borehole size beyond the 10 inch diameter or altering the physical properties of the ANFO product will not increase its detonation velocity. The type of confinement surrounding the ANFO affects the detonation velocity and its ability to sustain a detonation in smaller diameter boreholes.

ANFO can be made detonator sensitive to a number 8 test blasting cap by reducing the size, by crushing, the ammonia nitrate prills. The basic ANFO product is not detonator sensitive and does require a suitable primer. The minimum primer required for ANFO increases as charge diameter increases. There is a tendency to underprime in large diameter boreholes. A good rule of thumb is, when in doubt, use a larger primer. To prime ANFO, a high-energy primer is desirable. The detonation pressure of the primer should be greater than the detonation pressure of the ANFO. The priming of ANFO will assist in its reaching a steady state velocity within a minimum distance from the point of initiation. This quick effect of reaching a steady state velocity will effectively improve the performance of ANFO. Steady state velocity is defined as the characteristic velocity at which a specific explosive under specific conditions in a given charge diameter will detonate.

Boreholes that contain water should not be loaded with ANFO products not designed for that purpose because water quickly dissolves and desensitizes ANFO. Test have demonstrated that ANFO does detonate when mixed with small amounts of water but field experience has shown that good blasting results on a continuing basis can only be obtained when ANFO is loaded in completely dry boreholes.

ANFO products are usually delivered by bulk trucks and dispensed from bulk trailer storage or storage bins. ANFO is dispersed into boreholes from on-site bulk trucks or paper bags.

Different manufacturers produce different varieties of ANFO products, according to the consumer demand. The appropriate manufacturer can be consulted for ANFO energy requirements necessary for rock fragmentation and displacement.

SLURRIES

A slurry is a mixture of nitrate such as ammonium nitrate, a fuel sensitizer, either explosive or nonexplosive and varying amounts of water. Emulsions and watergels are slurries, and classified as water based explosives. An emulsion is somewhat different than a slurry in physical character but similar in many functional respects.

The principal differences are an emulsion's general higher detonation velocity and smaller particle size of ingredients. Slurries, watergels and emulsions can be treated as the same family of products with different manufacturer variations. Slurries contain large amounts of ammonium nitrate but are made water resistant by the use of gums and cross linking agents in watergels and emulsifiers in emulsions. The variety of slurry formations is almost infinite. The list of fuels include fuel oils, wax, aluminum and amine nitrate.

Slurries may be classified as either high explosives or blasting agents. Those that are sensitive to a number 8 test blasting cap are classified as high explosives. Those that are not sensitive to a number 8 blasting cap are classified as a blasting agent. Slurries have to be stored in magazines appropriate to their classification.

Slurries have excellent water resistance and a higher density than dry blasting agents such as ANFO. Slurry efficiency is increased by good oxygen balance, decreased particle size, increased density, increased charge diameter, good coupling, adequate confinement and adequate priming. Slurry agents tend to lose sensitivity as their density increases even though they function quite well up to a density of 1.6. the consistency of slurry may range from a liquid to a gel.

Cartridged slurries for use in small diameter boreholes are made detonator sensitive so they can be substituted for dynamite. The sensitivity and performance of some grades of slurries are adversely affected by low temperatures. Slurries designed for medium diameter boreholes (2 to 5 inches) may be detonator sensitive but they often are not.

Aluminized slurries are those with high energy sensitizers which are used for blasting hard, dense rock. The aluminum additives increase the cost. High energy slurries have improved blasting efficiency when used in combination with the primer at the toe or in another zone of difficult breakage.

Detonating cord downlines can have a harmful effect on the efficiency of blasting slurries, depending on the size of the blasthole and the strength of the cord. When using detonating cord downlines, the slurry manufacturer should be consulted concerning the effect of the cord on the slurry.

The slurry technology is constantly ongoing. New products are continually being developed.

DYNAMITE

Dynamite has performed admirably over the past 100 years but is being replaced by some manufacturers with other products. The principal shortcoming of dynamite is its nitroglycerin content which makes it hazardous to manufacture, transport, handle, and use. Over the years various percentages of nitroglycerin and diverse materials have been mixed to produce different types and grades of dynamites.

The following is some of the more commonly used dynamites: straight nitroglycerin dynamite, high density ammonia dynamite, low density ammonia dynamite, blasting gelatin, straight gelatin, ammonia gelatin, semi-gelatin and nitrostarch dynamite.

Nitroglycerin was the first high explosive and is the sensitizer used in most dynamites. Nitroglycerin-based explosives are the most sensitive commercial products used today, excluding detonators. This sensitivity offers an extra margin of dependability in the blasthole but are more susceptible to accidental detonation. Some operators prefer to use dynamite in small diameter boreholes because of this dependability. Nitroglycerin dynamites account for only 5 per cent of the explosives market and almost all of that is in small diameter borehole work. Nitroglycerin has a specific gravity of 1.6 and a detonation velocity of over 25,000 feet per second.

The extreme sensitivity to shock, friction, and heat of the nitroglycerin makes it extremely hazardous to use.

Nitroglycerin that is inhaled or absorbed through the skin acts as a blood vessel dilator causing a significant reduction of circulation to the brain. This reduced circulation to the brain results in the nitroglycerin headache.

Dynamite must be handled and stored in accordance with applicable state and federal regulations. Magazine storage should be such that the oldest stock is always used first. Dynamite that leaks nitroglycerin into the wrapped cartridges or deterioration of any type presents a very dangerous product to handle. The manufacturer should be consulted for disposal when dynamite has any signs of deterioration or nitroglycerin leaks.

There are three basic types of dynamite: granular, semi-gelatin, and gelatin. The basic distinction is that gelatin and semi-gelatin dynamites contain nitrocotton that combines with nitroglycerin to form a gel. Granular dynamites do not contain nitrocotton and have a grainy texture.

Dynamites differ in the materials used to provide their principal energy source. Nitroglycerin is the energy source used in straight dynamite while ammonium nitrate is the energy source used in ammonia dynamites. As compared to straight granular dynamites, ammonia granular dynamites deliver less energy, are less water resistant and are less sensitive to shock and friction. The safety and economy of ammonia dynamites outweigh any performance sacrifice of a straight dynamite.

When field conditions permit, low cost blasting materials such as ANFO are replacing dynamite, and gels are less sensitive than dynamite to accidental detonation from impact, shock, friction, etc.

BOOSTERS

A booster is an explosive used to perpetuate or intensify an explosive reaction. A booster is often, but not always, cap sensitive and does not contain an initialing device. The terms primer and booster are often confused and interchanged but indeed they serve different functions. A primer is used to initiate an explosive reaction and contains a detonator, detonating cord, etc., whereas a booster does not contain a detonator. Some dynamites and high strength ammonia gelatins, watergels and emulsions are used with dry blasting agents such as ANPO to intensify the explosive reaction. Watergels and emulsions are commonly used to serve as boosters for ANFO.

Large diameter boosters will assist a blasting agent to reach its steady state velocity in a short distance that enhances efficient fragmentation. Boosters are also beneficial in holes where wet hole bags of ANFO may be desensitized by water seepage because of long exposure prior to shooting. Boosters have a higher energy and density than blasting agents. Boosters are frequently inserted into a borehole as the main explosive charge, such as ANFO, is being loaded. Boosters increase the overall density and energy of the main explosive charge which will improve the performance of the main charge in some operations.

PRIMERS

A primer is that portion of the explosive charge consisting of a cartridge or container of explosives into which a detonator or detonating cord is inserted, the purpose of which is to initiate the main explosive charge. The primer may be a watergel cartridge, emulsion cartridge, dynamite cartridge, cast primer or other detonator-sensitive explosive. A primer must have sufficient energy to initiate the detonation reaction in the main charge and sustain it until the primed explosive charge produces enough energy to support the detonation reaction by itself. The energy of the primer is derived from its density and size. As the difference between the diameter of the primer and diameter of the borehole becomes greater, the detonation pressure and energy density of the primer must be increased to maintain adequate priming. If the difference between the two diameters are large, the priming may be inadequate and the primer size must be increased. A primer functions best when its diameter is near the same size diameter as a borehole.

A basic principle of adequate priming is that the detonation pressure of the primer must exceed the detonation pressure of the explosives being primed. Priming has become more sophisticated in recent years with the introduction of ANFO, slurries, emulsions, etc. Inadequately primed explosives will either fail to detonate or will not deliver their maximum energy. The type and amount of primer are very important decisions which should be based on should technical advice by an explosive manufacturer. To get the full benefit of any explosive, the primer must have sufficient detonation pressure and density to develop a complete detonation reaction. When using ANFO, slurry, or an emulsion it is very important to ensure adequate priming. On a percentage basis of the total blast investment, the cost of an adequate primer is very small.

The effectiveness of a priming system is determined primarily by the detonation pressure, energy, and water resistance of the primer. The detonation velocity which is a factor of detonation pressure is also a dominant factor in the effectiveness of a primer. The water resistance of a prime~ should always exceed the water resistance of the explosive being primed. Most products designated as primers meet this standard.

Several products used for priming include dynamite, watergels, emulsions and cast primers which are popular, all of which can initiate a blast. Cast primers are available in various sizes, all of which are assembled in the same manner. They can be initiated by electric and nonelectric blasting caps or detonating cord with 50 grains per foot or stronger. Cast primers usually have a hole through the middle called a tunnel and a partial hole known as the cap well into which a cap fits. Electric and nonelectric detonators should be completely seated in the cap well. Detonating cord is inserted all the way through the primer with a secure knot tied at the bottom of the primer. Detonators should never be forced into a cast primer. If the hole in the primer is too small for the detonator, do not use the primer and contact the primer manufacturer. Primers should not be made up until immediately before insertion into the borehole. This serves to minimize the time that blasting caps and the primer are together and reduces the potential for accidental detonation. Cast primers are most commonly used to prime large diameter boreholes. Primers should never be made up in a magazine or near other large quantities of explosives and never make up more than necessary for immediate needs.

The primer manufacturer should always be contacted anytime when the user is not familiar with its transportation, storage, use, etc. The explosives supplier should be consulted for specific priming recommendations.

The priming area, which is the point of initiation in an explosive column, should be at the point of most confinement. In most cases this will be at the bottom of the hole, however there are exceptions, particularly in surface coal mines where there may be a soft shale layer above the coal and harder sandstone further up the column. In this type of situation, the primer should be located in the harder sandstone seam. Except in extremely shallow holes, a second primer with a detonator with a later millisecond delay are sometimes used near the top of the explosive column. This will prevent unfired explosives in the muck pile due to cutoffs from shifting rock or from column interruption. Oversize material from a hard cap rock can be reduced if both primers, top and bottom, are initiated with detonators having the same delay times. The principles of priming apply to all size holes where ANFO or other blasting agents are used. Normally, the rock that requires the most explosive energy is at the bottom of the hole. The rock in this area must not only be sheared but must also be shattered and moved out. Care must always be taken in primer makeup to ensure that the detonator remains in the primer until the time of detonation. The detonator should be securely positioned within the primer with its base charge pointing toward the collar of the hole.

The primer is normally loaded at the bottom of the hole. This gives maximum confinement at the point of initiation and also guards against undetonated explosives in the bottom of the borehole if it becomes plugged or cut off during the blast. To avoid having the detonator fall out of a primer cartridge, the cartridge should never be split, rolled or deformed in any manner. A primer should never be tamped under any condition.

The primer is usually loaded at the bottom of the hole in large diameter boreholes. Bottom initiation serves to maximize confinement of the charge. Where subdrilling is used, the primer should be located at the toe level rather than the bottom of the borehole to help reduce ground vibration. Bottom initiated holes tend to produce less flyrock and airblast than top initiated holes, assuming all other blast dimensions are equal. Top priming is seldom recommended except where a hard layer of rock is present in the upper portion of the bench. A rule of thumb, when using a single primer in a large diameter borehole, is to place the primer in the zone of most difficult breakage which will normally be the toe area.

There are some situations in which multiple primers are used in a single borehole. Multiple priming is required when deck charges are used. Deck charges are used to (1) reduce the powder factor in a blast, (2) to break up boulder type caprock in the stemming area of the blast, (3) to reduce the charge weight per delay to help reduce ground vibrations. To reduce the charge weight, each deck in the hole will be on a different delay. To reduce the powder factor and to break boulder caprock in the stemming area, the decks in a single hole may be on the same or different delays. In any case, each deck requires a separate primer. Multiple priming is also used as a safety factor to assure total column detonation. With most explosive products, once detonation has started it will proceed efficiently through the column of explosives. However, very long thin charges or slip planes in the rock strata may offset the explosive column and cause part of the column not to propagate. In these cases two or more primers may be spaced throughout the explosive column. With multiple delayed decks in a borehole, detonation should proceed from the bottom up where a good free face exists.

Multiple priming will help ensure total column detonation when rough boreholes are encountered. Multiple priming will also help minimize cutoffs and assist in increasing the detonation rate. Multiple priming is also recommended in the following cases: (1) in water filled holes where the sensitivity of the main charge may be affected by water seepage, (2) when using insensitive packaged ANFO products that have poor cartridge to cartridge sensitivity.

Primer safety is of the utmost importance. Primers should be made up close to the blast site and immediately before loading. Care must be taken to assure that the detonator or detonating cord does not come out of the primer. A primer should never be tamped or dropped into a borehole.

When priming small diameter cartridges such as dynamite, emulsions or watergels, the detonator is inserted in a punched hole of the explosive and half-hitched around the cartridge. Two half hitches are commonly used.

When priming large diameter cartridges with electric detonators, a diagonal hole is punched from the top center of the cartridge and out the side about eight inches from the top. The legwires are doubled over, threaded through the hole and wrapped around the cartridge. The detonator is placed in a hole punched into the top of the cartridge and pulled tight. Tape may be used for extra security. For maximum efficiency, the diameter of cartridge primers should be as near to borehole diameter as can be conveniently loaded. Gelatin dynamites are preferred over granular dynamites when priming because of their higher density, velocity, and water resistance. Some granular dynamite primers may be desensitized with prolonged exposure to water or to the fuel oil in ANFO.

The priming of an explosive column in wet or water filled boreholes present several factors that must be considered. Loading in water always presents the possibility of cartridge separation. Because of the insensitivity of products such as ANFO, manufacturers recommend a primer be placed after every two cartridges in the column. These products should be primed with some type of cast or high density, high velocity, water resistant watergel or emulsion explosive.

Every primer should be handled with the realization that its potential hazard is greater than either the detonator or the explosive when separated. The primer is more sensitive than the explosive alone because of the presence of a detonator and the primer is more destructive than the detonator alone because of the total weight of the primer. Primers should be assembled during loading operations to reduce exposure time to hazards of heat; impact, and friction.

EXPLOSIVE CLASSIFICATION

The U.S. Department of Transportation has classified explosive materials according to their hazard potential.

Class A Explosives: This is the class that possesses the maximum electric and non-electric blasting caps, detonating cord, MS connectors, primers, etc. All those explosive products that can be detonated by a number 8 test blasting cap are classified as class A explosives and must be handled with caution. This test consists of placing the material to be tested in a container with a number 8 blasting cap. The cap is detonated to determine if the material will detonate.

Class B Explosives: This class possesses a flammable hazard and includes fireworks. Class B explosives do not have a particular application to surface mining and does not warrant further discussion in this study guide.

Class C Explosives: This class possesses a minimum hazard and includes, primarily, blasting agents such as ANFO and low sensitivity watergels.

EXPLOSIVES AND EXPLOSIVE SELECTION CRITERIA

The coal mining industry in the United States is the largest consumer of explosives and use over half of the explosives that are used in this country. Mining operations use large amounts of the blasting agent ANFO (ammonium nitrate-fuel oil). These operations are responsible for the fact that ammonium nitrate products account for an excess of 80Z of the explosives consumption. During the past thirty years, ANFO and its related products have replaced dynamite in dry holes because of cost savings, safer handling characteristics and mechanical loading ability.

Efficient fragmentation and displacement of overburden material are the critical factors to increased productivity and profitability. Good breakage and displacement are directly dependent upon the use of proper techniques in the blasting operation.

The proper selection of an appropriate explosive material is an important part of blast design that is needed to assure a successful blasting program. Explosive selection is dictated by economic considerations and field conditions. The blaster should select a product that will give the lowest cost for broken rock, while assuring that fragmentation and displacement are adequate for efficient movement by the equipment being used. Factors which should be taken into account in the selection of an explosive include explosive cost, charge diameter, cost of drilling, fragmentation difficulties, water conditions, atmospheric conditions, ground propagation, storage consideration and sensitivity considerations.

No other explosive product can compete with ANFO on the basis of energy cost. Both of the ingredients, ammonium nitrate and fuel oil, are relatively inexpensive. The safety and ease of storage, handling and bulk loading add to the attractive economics of ANFO. Slurries and dynamite costs range from slightly more than ANFO to as much as six times the cost of ANFO, depending on the addition of high energy ingredients. ANFO is not always the best product for the job because it has several shortcomings. ANFO has no water resistance, it has a low specific gravity and under adverse field conditions it tends to detonate ineffectively.

The dependability and efficiency are sometimes reduced at smaller charge diameters, especially in damp conditions or with inadequate confinement. When using charge diameters less than 2 inches, many blasters prefer a cartridge slurry or dynamite despite the higher cost. The performance of ANFO in a 4-inch diameter blasthole is better than at 2 inches. Bulk loading in the 2 to 4 inch diameter blastholes offers attractive economics. Bulk loaded ANFO or slurry should be used in blasthole diameters larger than 4 inches unless there is some compelling reason to use a cartridge product. ANFO's efficiency and dependability increase as the charge diameter increases.

The blaster should select the lowest cost explosive that will give adequate dependable fragmentation. When drilling costs increase such as in the case in hard, dense rock, the cost of explosives and the cost of drilling should be compared and controlled by experimentation and careful cost analysis.

When drilling is expensive, the blaster may want to increase the energy density of the explosive, even though at an added cost. The explosive manufacturer should be consulted for advice and recommendations in this technical area. Gelatin dynamites will give higher energy densities than granular dynamites, if dynamites are used. The energy density of a slurry depends on its density and proportion of high energy ingredients. The individual manufacturer should be consulted for a recommendation on a high energy slurry. The energy density of ANFO can be increased by the addition of finely divided aluminum. The economics of aluminized ANFO improve where the rock is more difficult to drill and blast.

Expensive drilling and fragmentation difficulties go hand in hand because hard, dense rock may cause both. A high detonation velocity does help in fragmenting hard, massive rock. The individual manufacturer should be consulted for a recommendations on a high velocity product. The detonation velocity of ANFO is dependent on its charge diameter and particle size. ANFO detonation velocity will maximize in 10 to 15 inch diameter blastholes and drops by one third as much in 2 inch diameter blastholes.

Even though ANFO is one of the most common and economical blasting agents, it does not have any water resistance. Wet-hole bags or blasthole liners must be used when wet conditions are encountered. An explosive manufacturer will specify the water resistance of their particular product.

Atmospheric temperatures were not an important factor in selecting an explosive until slurries were developed. Dynamites employ low-freezing explosive oils which permit their use in the lowest temperature. ANFO and slurries are not seriously affected by low temperatures if priming is adequate. At low temperatures, some slurries may lose their detonator sensitivity but will still function well if adequately primed. When slurries are to be used in cold weather, the manufacturer should be consulted about the temperature limitation factors.

Ground propagation is the transfer or movement of a detonation from one point to another point. Propagation between holes is undesirable because it negates the effect of delays. Propagation between holes will result in poor fragmentation, failure of a blasting round to pull properly, excessive ground vibrations, air blast and flyrock. The problem is most Serious when using small boreholes. Small boreholes require small burdens and spacings and therefore increase the risk of hole to hole propagation. Water saturation and blast site deviation compound the problem. The use of a less sensitive product will help the problem when hole to hole propagation is suspected even though inefficient fragmentation, excessive ground vibration and air blast may result.

The magazine construction and storage requirements are less stringent for blasting agents than for high explosives. High explosive magazines must be well ventilated and resistant to bullets, fire, theft, and weather whereas blasting agent magazines need only be weather and theft resistant. This is an additional point in favor of blasting agents. ANFO may be stored in bulk trailers or bulk bins whereas high explosives are stored in steel magazines that must meet additional construction requirements.

The sensitivity considerations address questions of the safety and dependability of an explosive material. Sensitive explosives such as the dynamites are more susceptible to accidental detonation by spark, or friction than blasting agents such as ANFO. Slurries and nitrostarch based explosives are less sensitive to accidental detonation than nitroglycerin-based explosives such as dynamite. The more sensitive explosives, with all other conditions being equal, are less likely to misfire. Accidental impact from a drill bit is less likely to detonate a blasting agent than a dynamite. This does not mean that a blasting agent will not detonate when accidentally impacted. The dynamites are less likely to misfire than blasting agents when exposed to adverse conditions, blasthole charge separation, small charge diameters or low temperatures. Most of the dynamites used today are used in construction, small quarries and underground mines, even though dynamite is used as primers and boosters in some surface operations. Dynamites, blasting agents and slurries all have a place in small diameter blasting when safely handled, stored, and used properly.

UNIT III

EXPLOSIVE AND BLASTING AGENT PROPERTIES

EXPLOSIVES AND BLASTING AGENT PROPERTIES

Explosives and blasting agents are characterized by various properties that determine how they will function under field conditions. Each product has certain specific properties. Methods of measuring these properties have been developed to relate them to rock breakage. By knowing what properties are critical to performance, new explosives can be designed to work with greater efficiency. Properties of explosives which are particularly important to the blaster include water resistance and wet borehole loading, sensitivity, detonation velocity and density.

WATER RESISTANCE

Water resistance is defined as the number of hours a product can be submerged in static water and still be detonated reliably. This time is affected by the depth of water and whether it is static or moving. Explosive products penetrated by water will have their efficiency impaired first. Secondly, prolonged exposure or in severe water conditions, they may become desensitized to a point where they will fail to detonate. The water resistance of a product depends on the packaging, product inherent ability to withstand water and the water conditions. Static water at low pressures will not affect the explosive as quickly as fast moving water. The emission of brown nitrogen oxide fumes from a blast usually indicates inefficient detonation caused by water deterioration. The emission of these fumes signifies the need for a more water-resistant explosive or external protection from water in the form of a plastic sleeve or a waterproof cartridge.

Explosives differ widely in their ability to resist the effect of water penetration. Bulk ANFO prills have no water resistance and would not be used in the water filled portions of a borehole. ANFO will quickly desensitize in borehole water. Packaged ANFO products, when used in wet works, depend entirely on their packaging to resist water penetration. Borehole polyethylene liners or plastic bags are used to resist water penetration but they offer minimal water resistance when loaded into water filled boreholes.

These low density products can become separated by floating in water or mud in the borehole. The priming or boosting of every two units may help to overcome the substandard performance created by this problem. When using products with minimal water resistance such as ANFO, these products should be detonated as soon as possible after loading.

Products such as gelatin dynamite, emulsions and watergels have good water resistance. Nongelatinized high explosives have poor to good water resistance. Despite their inherent water resistance, gelled products can become desensitized under some severe field conditions. In water conditions, these products should not be removed from the packaging and they should not be cut into small sections. The packaging does improve the product’s water resistance and cutting the explosive into pieces reduces the effective water resistance by increasing the surface area exposed to water.

SENSITIVITY

The sensitivity of an explosive is defined as the minimum energy, pressure or power required for initiation. There are numerous measures of sensitivity, including cap test sensitivity, drop tests, bullet tests, friction tests and others. The number 8 detonator sensitivity test is the standard used by the explosive industry. This sensitivity test characterizes an explosive's ease of initiation and is also used to classify explosive products. Sensitivity to a number 8 detonator under test conditions means that a product is classified as an explosive. Lack of test sensitivity results in a classification as a blasting agent. The sensitivity test is performed by placing an explosive product in a quart container with a number 8 test detonator and fired to determine if the material will detonate. Sensitivity among blasting products varies considerably and is dependent upon ingredients, particle size, density, charge diameter, confinement, the presence of water, and often temperature with slurries. Manufacturers usually recommend a primer for their products based on field data. In general, products that require larger primers are less susceptible to accidental initiation and are safer to handle. Explosive products are made to detonate and regardless of their safety factor should never be abused in any way.

Sensitiveness, a closely related property to sensitivity is often confused for sensitivity. Sensitiveness is the capability of an explosive to propagate a detonation from hole to hole under some conditions. An explosives may propagate from hole to hole under some conditions. An insensitive product may fail to propagate throughout the borehole length if the borehole diameter is too small. Sensitiveness is closely related to critical diameter, which is the smallest diameter at which an explosive will propagate a stable detonation. Manufacturers give recommended minimum diameters for individual explosives. Some types of explosives are so sensitive that they will propagate between boreholes over considerable distances depending on the material to be blasted, the explosive, the size of the charge, the distance between boreholes and the presence of water. It is important that individual borehole charges do not propagate between holes but rather detonate independently according to the predetermined delay interval. ANFO and watergels have a reduced tendency to propagate between holes when compared to more sensitive products such as dynamite.

FUMES

Every detonation of an explosive or blasting agent produces a measurable amount of toxic gases, primarily carbon monoxide and oxides of nitrogen. Detonation gases also include carbon dioxide, nitrogen, steam and monoxide and should always be avoided. Exposure to smoke can cause personal injury. Smoke should always be avoided because it may contain poisonous gases such as carbon monoxide and nitrogen oxides. Both the nature and total quantity of poisonous gases and smoke vary between types of explosives. Most blasting products are oxygen balanced to minimize fumes and to maximize energy release. The following factors increase fumes and toxic gases: poor product formulation, inadequate priming, insufficient water resistance, lack of confinement, reactivity of the explosive with the material blasted, removal of explosive wrappers and incomplete product reaction. Adequate waiting periods are mandatory before returning to a blast area. Some toxic gases are colorless and odorless. An absence of post blast smoke is not a guarantee, that hazardous levels of toxic gases are not present. Never return to a blast area until the smoke and toxic gases have had a sufficient time to dissipate into the atmosphere.

DETONATION VELOCITY

The detonation velocity of an explosive is the speed, in feet per second-FPS or meters per second-MPS, at which the detonation wave travels through a column of explosive. It ranges from 5,000 FPS to 25,000 FPS for commercial explosives used today. A high detonation velocity gives the shattering action that many experts feel is necessary for difficult demanding requirements that is normal for most blasting jobs. The detonation velocity of ANFO and slurries may vary considerably depending on field conditions. Many factors affect the detonation velocity, including product type, diameter, confinement, temperature, and degree of priming. The detonation velocities range from 5,000 FPS for ANFO to 25,000 FPS for detonating cord. The diameter of a product will influence the velocity, up to a certain diameter, depending on the type of explosive. In general, the larger the diameter, the higher the velocity, until the maximum velocity is reached. Every explosive has a critical diameter, which is the minimum diameter at which the detonation process, once initiated, will support itself in the column. In diameters smaller than the critical diameter, the explosive detonation will not be supported and will be extinguished. In general, the greater the confinement of an explosive, the higher the detonation velocity. The degree of confinement usually has less effect on the velocity as the diameter of the explosive increases. Changes in the temperature of an explosive will affect the velocity. A decrease in temperature will decrease the sensitivity of any explosive. The velocity of temperature will decrease the sensitivity of any explosive. The velocity of explosives which contain a liquid in some quantity, such as watergels, is more affected by temperature, although explosive formulations are designed to minimize this affect. Explosives that are solids at normal temperatures and contain little or no liquid are relatively unaffected at the normal low temperatures experienced in blasting. Priming has a very pronounced effect on velocity. Adequate priming will help ensure that the explosive is also ensure the explosive maximum velocity is reached as quickly as possible. Inadequate priming may result in failure of the explosive to detonate, a slow buildup to maximum velocity or a low order detonation which amounts to a deflagration. Blasters should always ensure maximum velocity of the explosive by following the recommended priming procedures of the manufacturer.

DENSITY

The density of an explosive is one of the most important properties that should be considered in designing a blast. By knowing the explosive density, blasters can design shots of any size with the proper powder factor and powder distribution. Density is normally expressed in terms of specific gravity, which is the ratio of the density of the explosive to the density of water. Water has a density of 1. The density of most explosive products ranges from .8 to 1.6. Most packaged or free flowing ANFO has a low density of .8 to 1. Cartridge watergels, emulsions and dynamites generally range in density from .9 to 1.6, with most in the range of 1.10 to 1.35. products loaded into boreholes containing water must have a density greater than 1 in order to sink. A useful guide in designing a blast is to know how many pounds of explosives that will load in one foot of borehole. The density of an explosive determines the weight of explosives that can be loaded into a given column of borehole. Blasters should remember that density calculations are only good approximations because of variations in hole size from worn bits, soft strata of rock and variations in explosive compaction. Most explosive manufacturers produce a scaled chart that allows a blaster to match explosive density with borehole diameter in order to obtain the weight of explosives to load in each foot of the borehole.

UNIT IV

INITIATING DEVICES

INITIATING DEVICES

ELECTRIC DETONATORS

Electric initiation systems use an electrical power source to transmit electrical energy to detonators. Large numbers of electric detonators can be detonated from a safe location when the proper electrical energy is supplied and the blast wiring circuitry is complete. The types, circuitry design, wiring connections, and an efficient blasting machine are vital elements to perform a successful electric blasting program. Good results from any blasting operation can be achieved only when the initiating device used to detonate the explosive charge is carefully chosen and properly utilized. All detonators are made to explode, therefore they should be treated with the same care and caution as used with all high explosives. Detonators should never be physically abused, tampered with or altered in any manner or exposed to sources of extraneous electricity such as stray current, static electricity, electrical storms, high voltage power lines and radio frequency (RF) energy. Inappropriate treatment and lack of necessary safety precautions may result in premature detonation and serious injury or death. These explosive devices must be closely inventoried and absolutely locked up when not in use. Electric detonators are much more sensitive than explosive products such as ANFO, slurries, emulsions, etc.

An electric detonator has a cylindrical metal shell containing several powder charges. Electrical energy is delivered into the detonator by two, plastic insulated, metal wires called "legwires" which enter the detonator through a rubber or plastic plug. The plug is securely crimped in the open end of the cap shell to form a water resistant closure and firmly positions the legwire ends inside the shell. The ends of the legwires are joined together inside the shell by a short length of fine filament, high resistant wire called the "bridge wire". The bridge wire is embedded a heat sensitive, ignition mixture. Upon application of electric current the bridge wire heats sufficiently to initiate mixture causes the primer charge to detonate, subsequently detonating a high explosive base charge.

A considerable amount of energy is required to initiate a high explosive such as dynamite emulsion, watergels, cast primer, etc. High explosives are commonly initiated by an electric detonator. An electric detonator is a capsule containing a series of sensitive explosives that is initiated by an outside energy source. A detonator is placed into a container of high explosives or primer, which is placed into the column of main explosive charge such as ANFO, slurries, emulsions, etc.

An initiation system has three basic parts: (1) an energy source, (2) an energy distribution network that directs energy to each individual borehole, (3) an in hole component that uses energy from the distribution network or wiring circuitry to initiate an explosive. The energy source is usually a blasting machine. The energy conveyed to each borehole is delivered by the blast machine. The detonator, when inserted into a detonator-sensitive explosive and activated will initiate the explosive column.

Electric detonators vary in strength from a number 6 to a number 12, although a number 6 and number 8 are the most common. Although the number 6 and 8 are the most common, there is a trend toward higher strength detonators, particularly when blasting with sensitive products which are less sensitive than dynamite. The detonator strength depends on the amount and type charge in the detonator. Higher strength detonators have a greater quantity of base charge. In a delay detonator, the ignition mixture initiates a delay powder train which burns at a predetermined time before charge. The burning rate of the delay powder and the 14 determine the time interval between application of the electrical energy and detonation of the base charge. In most types of blasting measured in milliseconds, are required between the detonation of various boreholes.

Electric detonator "legwires" are solid conductors made of either copper or iron covered with plastic insulation. Copper legwires are the most widely used because they have the best electrical conductivity. Iron legwires are used where contaminants are removed by magnetic separation. The plastic insulation provides insulating efficiency, abrasion resistance and flexibility. The insulation wire covering is brightly color coded to provide identification and visibility.

All electric detonators should have shunts on the free ends of the legwires to help protect against unwanted current flowing through the bridge wire circuit. The shunt forms a short circuit of the legwires through the entire length and insulates the wires from most unwanted electric currents. The shunt should never be removed from an electric detonator until connecting the wires into the blasting circuit or when testing for continuity.

The use of delay blasting will help improve rock fragmentation, rock displacement; provide greater control of ground vibration, air blast and fly rock; reduce the powder factor and blasting costs.

The ultimate warning concerning the use of electric must be adhered to at all times: Electric detonators of different manufacturers should never be mixed in a blasting circuit because their ignition systems may not be electrically compatible and misfires may occur. Blasters should never attempt to fire electric detonators either more or less electric current than recommended by the manufacturer.

Electrical continuity tests should be performed on single detonators before loading the main explosive charge and after each series is hooked up. Only a blasting galvanometer or blasting multimeter should be used for this purpose. The manufacturer recommended current should be used to fire electric detonators. The legwires should be kept shunted until ready to hook up the blasting circuit. Electric detonators from different manufacturers should never be mixed in the same blasting circuit. Extreme caution from direct contact and stray current should be taken when blasting near power lines. A blaster should be taken when blasting cables of any kind near electric detonators. An electric detonator circuit should be completely insulated from the ground or other conductors such as bare wires, rails, pipes or other potential sources of stray current. A blaster should never uncoil the wires or use electric detonators in the vicinity of radio frequency transmitters, except at safe distances as specified by the manufacturer and IME publication number 20. Static electricity may cause a premature detonation of electric detonators.

PRIMING DEVICES

The process of priming has become more and more sophisticated since the introduction of non-detonator sensitive watergels, emulsions, and ANFO products. The major setback of inadequately primed explosives is that they will either fail to detonate or will not deliver their full potential energy. With the realization that a priming device is used to initiate a main explosive charge, a variety of primers are available from different manufacturers. A general priming rule is that the business end of the detonator should be directed toward the main explosive charge but there are variations of priming. Even though detonating cord is classified as a high explosive, a suitable primer is required to initiate an explosive column of ANFO, slurry, emulsion, etc. Detonating cord should be secured to the primer. Primers should never be tamped or abused in any manner. It is economically sound to use they type, size and number of primers that is known to insure reliable and efficient priming with a margin of confidence.

Priming devices are classified as high explosives and have to be stored accordingly. Priming devices should be made up with manufacturer recommended, prove and established methods. A blaster should make sure that the detonator shell is completely encased in the primer cartridge or cast primer and secured such that while loading no tension will be placed on the wires or detonating cord at the point of entry into the detonator. Detonating cord should be firmly tied to the primer cartridge or passed through the appropriate hole or holes in the cast primer. A detonator should never be forced into a primer cartridge.

Cast primers are predominantly used in large diameter boreholes, although some operators prefer to use cartridged high explosives. Regardless of the type of primer, it should fill the diameter of the borehole as near as possible. Most blasting agents detonate at a low velocity at the point of initiation with velocity building up until the explosive column reaches its stable velocity. This build up occurs within about three charge diameters. Low initial velocities can result when the primer is too small, of inadequate strength or when the blasting agent is poorly mixed or partially desensitized by water.

NONELECTRIC DETONATORS

The nonelectric detonators and nonelectric systems were developed in the 1970's. The purpose of development was to combine the advantages of electric and detonating cord systems. These systems are relatively new to the surface blaster in the coal mining industry due to their limited use because of preconceived ideas of complexity.

Nonelectric detonators are similar to an electric blasting detonator with one or two small tubes extending from the shell in a manner similar to legwires. These tubes contain an explosive material that propagates a mild detonation which activates the detonator. Delay periods are similar to those of electric detonators. This initiation system creates little or no air blast, does not disrupt the charge in the borehole and has delay accuracies similar to those of electric or detonating cord systems. A blaster should always remember that electrical storms are an extreme hazard with any initiation system. The nonelectric system is checked through a nonelectric system such as detonating cord because they can perform a continuity test on an electrical circuit whereas this test cannot be performed on a nonelectric system.

The nonelectric systems are different and unique among the different manufacturers. The more common nonelectric systems include detonating cord, shock tube and gas detonation. These nonelectric systems employ the use of nonelectric detonators. Due to the variations and complexities of these systems, the nonelectric systems, shock tube and gas detonation will not be discussed in this study guide. Intensive training should be conducted by a manufacturer consultant before using any type of nonelectric system.

DETONATING CORD

Detonating cord is a round, flexible cord that contains a center core of high explosives. The explosive core, usually pentaerythritol tetranitrate (PETN) is covered with a waterproof plastic sheath and has reinforcing coverings that have combinations of textile, plastic and waterproofing materials. These coverings help protect the cord from damage caused by physical abuses, exposure to extreme temperatures, water, and oil. The coverings also provide essential features such as tensile strength, flexibility and desirable handling characteristics. Detonating cord is available with PETN core load ranges from 1 to 400 grains per foot.

Detonating cord contains a center core of high explosives and has to be stored and handled according to the high explosive classification. Detonating cords are a safe and reliable nonelectric detonating device. Detonating cord initiation has been used for many years as an alternative to electric blasting where an operator prefers not to have an electric initiator in the borehole.

All cords can be detonated with a detonator and have a detonation velocity of approximately 25,000 (FPS) feet per second which is over four miles per second. Detonating cord is adaptable to most surface blasting operations and is the most widely used nonelectric system used in the coal mining industry. Detonating cord is relatively insensitive and requires a proper detonator, such as a number 6 detonator, for initiation. Despite this low sensitivity, PETN detonates at a speed of 25,000 FPS. Most detonating cord can propagate between sections if proper knots are used to tie the sections together. This quality provides cord versatility during loading. A number of different types and sizes of high energy cords are supplied in 1000 feet lengths. Detonating cords are manufactured for special purposes. Individual manufacturers should be consulted for recommendations when using detonating cord or any other type of nonelectric system.

The ends of detonating cord should be protected from water when used in a wet environment. PETN will slowly absorb water and will become insensitive to initiation by a detonator. Even when wet, detonating cord will propagate if initiated on a dry end. Manuals and data sheets should be obtained from the appropriate manufacturer to provide “working” knowledge and understanding of detonating cord characteristics before using such products.

Detonating cord, a detonator sensitive explosive, is used to detonate other high explosives with which it comes in contact and to transmit a detonation wave from detonating cord to detonating cord or to a nonelectric delay detonator.

The number of grains per foot, type, and thickness determine the cord's priming ability. PETN cords are relatively resistant to accidental detonation from impact, shock, friction and extraneous electricity. Despite this low sensitivity to abuse, detonating cords are high explosives and have been accidentally detonated prematurely on rare occasions. Detonating cord must be handled, stored, transported and used with respect, common sense and in accordance with state law, federal law and manufacturer recommendations. Detonating cords are well suited for the following purposes: (1) when operators prefer a nonelectric blasting system because of potential hazardous stray current, (2) when firing multiple charges of explosives without significant delay between charges, such as done in preshearing, (3) when multiple priming or decking in deep, large diameter borehole, (4) when blasting in difficult situations when it is hard to insulate electrical connections in electrical blasting.

The most common strength and most widely used detonating cords have 25 to 60 grains per foot. These strengths are used for trunklines, which connect the individual boreholes into pattern and for downlines, which transmit the energy from the trunkline to the primer cartridge. The lower strength cords are cheaper, some have less tensile strength and may be somewhat less dependable under harsh field conditions. Some cast primers are not dependable initiated by 25 grains per foot cord or lighter cord. Where possible to use, the lighter core loads offer an economy advantage, greater flexibility, and easier knot trying during field procedures. Detonating cord strengths of 100 to 200 grain per foot are occasionally used where continuous column of initiation of a blasting agent is desired. Cords of 200 to 400 grain per foot of PETN are occasionally used as a substitute for explosive cartridges' in very sensitive or small, controlled blasting jobs.

Cord strength lower than 25 grain per foot are sometimes used. Fifteen to twenty grain products may be used for small diameter holes and for secondary blasting. A blaster should consult with the appropriate manufacturer for the proper selection of the most practical and recommended cord strength.

To fully understand and appreciate the variations and purposes of the different cord strengths, a blaster can take note of a system that is based on low energy detonating cord. This system functions similar to conventional detonating cord except that the trunkline is low in noise, downlines will not disrupt the column of explosive, it will not initiate borehole products except dynamite and all connections are made with connectors rather than knots. The low energy cord of 2.5 grains per foot while low in noise will detonate. This system has provisions for both surface and in hole delays. Combining surface and in-hole delays give an unlimited number of delay combinations. As in the rule with all nonelectric systems, manufacturer consultants should provide information and training of such system before their introduction into any blasting program.

The priming and loading of explosives while using detonating cord have several factors that must be considered (1) borehole inspection (2) cord primer location (3) cord surface connections (4) cord surface cross ties (5) cord uplines, downlines, trunklines. In most blasting situations 50 grain per foot cord is preferred as the downline to initiate the primer reliability and tensile strength than the lower cords and also has greater economy than larger detonating cords. Cords with 25 grains per foot are sometimes used as trunkline. Cords are commonly used in large diameter boreholes for reasons of safety, prevention of cutoffs and multiple point priming.

The following is some of the basic procedures in loading large diameter boreholes with 50 grain detonating cord: (1) The full depth of the borehole is checked with a mirror or tape, the same as checking all in the boreholes. (2) The cord is attached to the first cartridge or primer loaded in the borehole and make sure the cartridge or primer goes to the bottom of the borehole. (3) A rod or spindle should be inserted thru the cord spool to facilitate handling. (4) Cut the cord from the spool after the first and the next borehole or a safe distance as soon as the cord is cut at each borehole. The cord spool should not be left connected to the cord spool because premature firing could propagate to other explosives piled near the borehole (5) Three feet or more of detonating cord should be allowed at the top of each borehole to compensate for any slumping of the first cartridge or primer deeper into the hole. (6) Draw the cord taut and hold it at one side of the hole so it wont' get broken or damaged. After loading each borehole, the cord should be fastened around a rock or other heavy object to prevent it from being kicked or pulled into the borehole.

Detonating cord is easy to connect for a blast. Most cords detonate between sections when spliced or joined together securely and tightly with the proper knots. The cord manufacturer should be consulted on the recommended way to splice or connect unusually large or small detonating cords.

The following is a list of general procedures when connecting sections of detonating cord: (1) Make sure the cut ends are free of water, oil or other contaminants. Connections or detonators should be placed at least 12 inches from the cut ends to insure positive initiation due to moisture absorption into the cut end. (2) Make sure all connections are made properly. Avoid sharp angles which may cause cord cutoff. Cutoff failures are caused when cord downlines slant back at an acute angle toward the main trunkline. (3) The cord should not be kinked, bent, scraped or slack left in the cord trunklines, borehole downlines or uplines. (4) Make sure all cord knots are tight and in good contact so they cannot work loose. Loose knots and insecure connections may fail to transmit the detonation wave. Avoid knots in the borehole. (5) Make sure every borehole has two paths by which the detonation can reach it and cross ties between the trunkline at regular intervals to provide positive detonation of the trunkline. More frequent cross ties should be provided when the spacing and burden are small. These cross ties insure against trunkline cutoffs due to ground movement or flying debris from previous fired holes. (6) Cut off the excess cord after tying in to prevent the excess from detonating across the trunkline and cutting it off. Keep the shot pattern clear of boxes, box liners, explosives, etc. such that the trunkline layout is readily visible, distinctive and neat. (7) When several cord downlines, uplines or trunklines are used, make sure they do not cross over each other. One cord may detonate prior to the other severing it causing it to fail. Taking the slack out of all cords can prevent this hazard. The trunklines should never cross over other lines in surface connections. (8) Trunkline noise can be reduced by (a) eliminating the trunkline and initiate each downline with electric detonators, (b) initiate the cord upline from the bottom of the hole with electric detonators, (c) covering the trunkline with twelve inches of fine material (d) using nonelectric delay detonators.

The knots and splices used for connecting detonating cord is a very important part for the safe use of cords. Cords should be spliced together with a square knot. The double wrap half hitch should be used to connect with a square knot. The double wrap half hitch should be used to connect (1) downlines, or uplines to a cord trunkline (2) cross-ties between trunklines (3) other right angle hookups. Clove hitching can be used to connect a relatively stiff downline to a flexible trunkline. Splices are not recommended in downlines or uplines inside a borehole for two reasons: (1) The splice may be broken or damaged during the loading or stemming operation of the borehole (2) Water may penetrate the exposed cord ends which could result in cord failure.

Most blasts that use detonating cord are delayed either on the surface or in the borehole. Surface delays though are more vulnerable to failures or partial failures due to ground movement. This problem can be minimized by the use of proper drill and delay patterns. The two most popular ways to surface delay a detonating cord blast are: (1) MS connectors in the cord trunkline (2) MS delay electric or nonelectric detonators attached to the cord downline. Cord uplines in deep boreholes that are bottom primed with delay electric blasting detonators can be used to multiple prime a borehole. The MS trunkline connectors offer the most convenient means of delays in detonating cord. The MS connectors are tied into the trunkline between the boreholes or groups of boreholes to sequence the blast in a predetermined order. These MS delay connectors have delay intervals of 5, 9, 17, and 25 milliseconds. Long exposure time to water, though can desensitize or lengthen the delay time of these connectors.

Very few detonating cord blasts today are not delayed, although some operators fire them instantaneously where ground vibration or air blast problems do not exist. A big incentive to fire cords instantaneously is the reduction of cord cutoffs due to ground movement. Even if cord delays are not used, it is very important to design a blast such that the cord fires the boreholes in proper sequence with respect to the open face and direction of intended rock movement. The biggest consideration is to design the pattern so that boreholes near the free face are initiated first and do not cut off later firing holes due to ground movement.

Short interval delay electric detonators have been used for firing detonating cord blasts. The delay electric detonators are attached on the surface, either to the downline at each individual borehole or to the trunklines connecting rows or groups of holes. Surface noise can be minimized because of elimination of the trunkline by using these delay electric detonators. This system requires as much wiring as a standard electrical blast pattern of equal size and the usual precautions must be observed to prevent premature explosions from stray current.

Nonelectric delay detonators can be used where electric detonators are not feasible. The nonelectric detonators are also used to delay different decks. Each deck is supplied with a delay detonator.

Detonating cord trunklines may be fired with electric detonators. The detonators are attached side by side along the cord with the business or charged end pointing in the direction that the cord will detonate. The detonators are securely fastened to the side of the cord with tape. Caution should be taken to prevent the end of the cord, where the detonators are attached, from becoming wet.

Bottom hole delay systems are used in some blasting situations. These situations include: (1) In residential areas where detonating cord trunklines could create excessive noise levels. (2) In blast patterns and rock formations that could cause borehole cutoffs. (3) In tight shooting conditions which require bottom hole initiation for adequate rock fragmentation and displacement. Some operators may choose, in deep holes, to use an MS delay detonator and primer in the bottom of the borehole supplemented by detonating cord upline which is tied in and initiated by the primer assembly. This arrangement provides a convenient method for multiple point priming in which cast primers or detonator sensitive cartridges are slid down or alongside the upline to minimize borehole cutoffs and failures due to separations in the powder column.

Nonelectric delay detonators were developed to provide a system for bottom hole initiation of explosives. These detonators would not be as sensitive to normal sources of hazardous extraneous electricity as electric detonators. These detonators consist of a small detonating cord which convey the detonation wave to a delay detonator. A special plastic connector at the end of the detonating cord enables tying each borehole into a trunkline. These units are available in a millisecond delay series and a long period delay system with time intervals similar to electric delay detonator. Nonelectric detonators can be connected to the trunkline by means of a special plastic connector or with a standard, double wrap half-hitch knot.

Detonating cord used in small diameter boreholes present several shortcomings that must be considered. Detonating cords used to initiate primers in small diameter holes (less than four inches) can sometimes cause low-velocity detonations of ANFO products. In bottom priming of these small holes, the detonating cord shoots through the ANFO column before reaching the primer and degrades the ANFO and may cause a partial detonation.

This results in a low order rate of detonation for part of the ANFO and could be a substantial reason for poor or inconsistent breakage of the hole. Wherever possible, detonating cord should not be used in ANFO loaded into holes that are less than four inches in diameter.

The following precautions should be observed when using detonating cord: (1) Select a detonating cord that has the physical performance characteristics that are consistent with correct blasting methods and types of explosives, primers and boosters that are to be used. (2) Handle detonating cords with the same respect and care given to other explosives products. (3) Handle and use detonating cords with great care to avoid damaging or severing the detonating cord prior to firing. (4) Cut and damaging or severing the detonating cord prior to firing. (5) Make positive and tight connections in accordance with manufacturer recommended and established methods. (6) Knot type and other connections should be made where the detonating cord is dry. (7) Avoid loops, sharp kinks or angles that may direct the detonating cord back toward the oncoming line of detonation. (8) Don't attach any detonator to the detonating cord until everything else is in readiness for the blast. (9) Connect detonators to detonating cords by positive methods as recommended by the manufacturer and be sure the detonator is always pointed in the desired direction of the cord detonation. (10) Make sure the cord is firmly tied to the primer cartridge or passed through the appropriate hole or holes in a cast primer or secured with an appropriate knot if applicable. (11) Separate detonating or secured with an appropriate knot if applicable. (11) Separate detonating cord from other explosives if permitted to transport in the same vehicle. (12) Store detonating cord in an appropriate magazine as recommended by the manufacturer and in accordance with state and federal law. (13) Never strike, tamper with or attempt to investigate the contents of any detonating cord. (14) Never attempt to reclaim or use detonating cord that has been water soaked even if apparently dried out.

Two of the primary advantages of detonating cord initiation systems are their ruggedness and their insensitivity. Detonating cords function well under severe conditions such as in hard, abrasive rock, wet holes, and deep large diameter holes. Cords are not susceptible to electrical hazards, although lightning is always a hazard at any blast site. The nonelectric delay systems are extremely flexible and reasonably accurate.

Several disadvantages may be significant in certain situations. Systems that employ only surface connections for delays present the potential for cutoffs. Surface connectors also present the hazard of accidental initiation by impact. Detonating cord trunklines create a considerable amount of air blast. Detonating cords should be covered with 15 to 20 inches of dirt or fine material or else noiseless systems should be used when blasting near populated areas. Detonating cord downlines present the problem of explosive discharge or stemming disruption. These disruptions depend to a large degree on the borehole diameter, type of explosive and core load strength of the detonating cord. The means of checking the system is a visual examination. Vehicles should never pass over a loaded hole because the cord may be damaged, resulting in a premature ignition or possible misfire. A premature ignition could also result from driving over a surface delay connector.

MULTIPLE CONNECTORS

Multiple, millisecond (MS) connectors offer the most convenient and most common means of firing detonating cord blasts by the short interval delay method on the surface. The MS connectors are one of the most popular ways to surface delay a blast that uses detonating cord. The connectors are coupled or tied into the trunkline between the boreholes or groups of boreholes to sequence the blast in a predetermined order. MS connectors are manufactured with delay intervals that are generally used in small diameter holes drilled on closed spacing, while the longer intervals are used in larger diameter holes that have wider spacings. This type of delay firing covers 4 inch holes on 7 to 12 foot spacings and up to 17 inch holes on 25 feet or larger spacings. To help minimize cutoffs, a good rule of thumb is to allow at least 1 foot between holes for each millisecond of delay and to locate the connectors midway between the holes. The usual intervals are 5, 9, and 17 milliseconds. When several rows of holes are fired in sequence in a multiple row blast, cross ties with a connector will serve to insure a positive detonation.

MS connectors must be protected from abusive shock, heat, impact, or friction because they have an impact sensitivity equivalent to blasting detonators. All unnecessary personnel and equipment should be removed from a shot area before MS connectors are tied into a blast circuit.

UNIT V

BLASTING PRACTICES

BLASTING PRACTICES

SMALL DIAMETER BLASTHOLE LOADING

The size of a blasthole or borehole is the first consideration of any blast design. The borehole diameter, type of explosive and the type of material to be blasted will determine the blast dimensions. In some operations, a blaster will have the freedom to select the borehole size whereas in other operations a blaster will be limited to a specific size borehole based on available drilling equipment. Borehole diameters for surface mining will range from 2 to 17 inches. In comparison, more small diameter boreholes will have to be used versus a lesser number of large diameter boreholes to properly fragment a similar amount of material.

Boreholes are usually classified as small diameter when less than 4 inches in diameter. Regardless of size, boreholes should never be loaded with explosives during the approach of an electrical storm.

Small holes, due to a larger number of holes required will yield high drilling and blasting costs. Small holes cost more to drill, explosives are more expensive, and the cost of detonators will be higher. The fragmentation will usually be finer and more uniform that will result in lower loading, hauling and crushing costs. Secondary blasting and toe problems will be minimized in small borehole blasting. The size of equipment and economics will dictate the type of fragmentation needed and therefore the size of the borehole to be used.

Ground vibration is easier to control with small boreholes as compared to large boreholes. These vibrations can be partially controlled by reducing the weight of explosive per delay interval. In the final analysis, the selection of the borehole size is based on economics. Savings may be cut in the drilling and blasting program but may well be lost through increased loading, hauling, and ground vibration – air blast complaints.

The primer cartridge is normally loaded at the bottom of the hole in small diameter holes. This arrangement gives maximum confinement at the point of initiation and also guards against leaving undetonated explosives in the bottom of the borehole if it should become plugged during loading or cut off during the blasting process. A primer cartridge should never be tamped. A cartridge primer should never be slit, rolled or otherwise deformed to help prevent the detonator from falling out of the primer cartridge.

LARGE DIAMETER BLASTHOLE LOADING

Economics and efficiency favor the use of bulk loading in boreholes larger than 4 inches. The explosive main charge such as ANFO, slurries, etc. are cheaper, enhance faster loading and well coupled, bulk charges enhance blasting efficiency.

The following are practices that should be performed in large and small diameter boreholes: (1) The boreholes should be checked for the proper depth and condition prior to loading any explosive material. A weighted tape measure or a tamping pole can be used to check for the proper depth. Boreholes that are deeper than the intended depth should be filled with drill cuttings or stemming material up the proper level. Excessively loaded boreholes are a waste of explosives and increase ground vibrations. (2) Boreholes that are less than the planned depth should be cleaned out or redrilled. (3) Obstructed holes should be redrilled. (4) A blocked hole should be filled with stemming if an adjacent hole has to be drilled to replace a blocked hole. If this is not done, the new hole may shoot into and vent through the blocked hole causing flyrock, air blast, and poor fragmentation. (5) Boreholes should be checked for water. (6) Boreholes that pass through or into an opening must have a special function performed. A plug should be placed in the borehole if the opening is located at the bottom of the hole. Openings along the length of the borehole should be filled with stemming material and multiple priming is required in this type hole.

ANFO, slurries and emulsions give the best economy in large diameter boreholes. ANFO is the most common product used in the coal mining industry.

Wet boreholes present problems that must be handled appropriately. ANFO that will be used in wet boreholes must be loaded in water-resistant, polyburlap packages. Wet hole ANFO is partially pulverized and densified so that the packages should be carefully lowered into water filled holes rather than dropped because a broken bag will result in desensitized ANFO and most likely, some unfired ANFO. Two disadvantages of waterproof, wethole ANFO is that some borehole coupling is lost and some heat will be lost to the water which will reduce energy released. Dewatering should be considered if possible when wet boreholes are encountered.

Different types of explosives may be used in large diameter boreholes. Large diameter dynamite cartridges are seldom used today except for occasional use as a primer. ANFO and slurries are most often used. ANFO boreholes are usually loaded from bulk trucks or hand poured from 50 pound bags. Premixed ANFO is usually delivered to most mining operations. Auger loading from bulk trucks gives the fastest loading rate. Some bulk trucks are equipped with a meter to measure the amount of explosive material delivered into a borehole. Hand pouring of ANFO is practiced at some operations where the expense of a bulk truck is not justified. Hand pouring gives the same complete coupling as bulk loading. Bulk slurry is usually pumped into large diameter boreholes. ANFO bulk loading offers advantages over loading of packaged products: (1) Cheaper Product. (2) Faster Loading. (3) More efficient use of borehole space. A bulk slurry truck may deliver a plant-mixed product to the borehole or it may carry separate ingredients for onsite mixing. Onsite slurry mixing is more complex than ANFO mixing and is usually done by explosive distributor. Hand pouring of slurry from polyethylene packages is practiced at some operations where bulk-truck loading is not practical. Pouring gives the same coupling as bulk-truck, loaded slurry.

BLAST DESIGN – ROCK CHARACTERISTICS

Rock characteristics are a major factor in designing a surface blast. A blast design is not a precise science. Rock mass has a wide variety in geology and structure. With the varying nature of rock, geologic structure and explosives, it is impossible to set down a series of equations or specific instructions which will enable a blaster to design a blast without some field testing. Some tradeoffs may be necessary in designing a specific blast for a given situation. Blasting concepts are used as an approximation for blast design and for troubleshooting the cause of a bad or inefficient blast. Field testing for specific mining may be necessary to refine individual blast dimensions.

Two overriding principles must always be remembered during the blast design process: (1) Explosives function best where there is a free face approximately parallel to the explosive column at the time of detonation. (2) There must be adequate space into which broken rock can move and expand. Excessive confinement of explosives is the leading cause of poor blasting results such as backbreak, ground vibrations, airblast, unbroken toe, flyrock and poor fragmentation.

The character of the rock mass is a critical, variable factor affecting the design and results of a blast. Rock characteristics vary greatly from one part of a mine to another or from one end of a job to another. Firsthand knowledge of a rock mass must be taken into account when making decisions on explosive selection, blast design and an appropriate and delay pattern. A blaster must be familiar with these variable factors in order to conduct a safe and efficient blasting operation. The variations in the character of rock cover a very wide range of possibilities which a blaster must have a least a general idea of how to handle appropriately.

A good driller provides a vital key in helping a blaster characterize a rock mass. Rock planes, joints, cracks, faults, open beds, cavities and zones of incompetent rock that may be detected by a driller will aid a blaster in designing a blast. A driller and a blaster should have a close working relationship in developing and maintaining a successful blasting program.

A driller can be of great importance while assisting a blaster in assessing rock variations that are no apparent from the surface. Slow drill penetration and excessive drill noise and vibration indicate a hard rock that will be difficult to break. Fast drill penetration and a quit drill indicate a softer, more easily broken zone of rock. A total lack of drill resistance to penetration accompanied by a lack of cuttings or return of water or air means that the drill has hit a void zone. A lack of drill cuttings or a return of water may also indicate an open bedding place or crack. An accurate drill log should be maintained at all times to indicate the depth and condition of all boreholes as well as the depth at which cracks, voids, water, etc. are encountered. A driller should always document these changes in the color or nature of drill cuttings which will tell the blaster the location of various beds and abnormalities in the individual boreholes.

A certain amount of rock displacement is required for efficient removal by equipment. The density of rock is a major factor in determining how much explosive is needed to displace a given volume of rock. This density is used to compute the powder factor. The burn to charge ratio varies with rock density from mine site to mine site. A geologist or an explosive manufacturer consultant can be of great assistance in helping to determine the applicable rock density and the appropriate powder factor. The hardness of a rock will most likely have a strong effect on blasting results. Soft rocks will be much more giving than hard rock. Soft rock that is slightly underblasted will most likely still be diggable while soft rock that is overblasted will not usually cause excessive violence. Slight underblasting of hard rock will usually result in a tight muck pile that is difficult to dig while overblasting of hard rock will most likely cause excessive flyrock and air blast. Blast designs for hard rock require closer control and tighter tolerances than for soft rock.

Unforeseen voids and zones of weakness such as cavities, underground mines, auger holes, mud seams, and faults are serious problems in blasting. Explosive energy will always seek the path of least resistance. A rock burden that is composed of alternate zones of hard material and incompetent material or voids will cause the explosive energy to be vented through the incompetent zones that will most likely result in poor fragmentation. Depending on the location of the zones of weakness with respect to free faces, excessive violence in the form of air blast and flyrock may occur. A particular serious problem is present when a borehole intersects a void zone. Particular care and caution must be taken while loading the charge to prevent the void from filling with a heavy concentration of explosive. An overload of explosive charge into a void area will usually result in excessive air blast and flyrock. A valuable loss of explosive energy will be lost to voids and zones of weakness.

It is vitally important that voids and zones of weakness be identified so that steps can be taken during borehole loading to avoid violence and improve fragmentation. The best mechanism for identification of these borehole irregularities is an accurate drill log.

The depth and location of voids and incompetent zones that are present in a drill pattern should be documented. A geologist, if available, can assist a blaster in plotting the trends of weak seams, voids and fault areas. Stemming material, rather than explosives, should be loaded through these weak zones. Voids should be filled with stemming material. If they size of a void area is too large to fill with stemming material then it may be necessary to block the borehole just above the void before continuing to load the explosive column.

The rise of the powder column should be checked frequently as the boreholes are loaded. If a column fails to rise as expected, then a void is probably present. A deck of stemming material should be loaded at this point before loading continues. Frequent checking during borehole loading will help assure that adequate space is left for stemming if the column rises more rapidly than expected.

Alternate zones of competent and incompetent rock will usually result in blocky, large fragmentation. A higher powder factor will seldom correct this problem as it will usually cause the large, blocky material to be displaced farther. Usually the best way to alleviate this situation is to use small boreholes with smaller blast patterns in order to get a better explosive distribution. The explosive charges should be concentrated in the competent zones and in the incompetent zones should be stemmed wherever possible.

Jointing of rock layers can have a pronounced effect on both fragmentation and stability of the wall perimeter. Close jointing usually results in good fragmentation. Widely spaced jointing will very often result in a blocky muck pile because the joint planes tend to isolate large blocks. The best solution to insure adequate fragmentation is to use smaller boreholes with smaller blast pattern dimensions. The extra drilling and blasting expense may be justified by the savings in loading, hauling and possible secondary blasting. When possible, the perimeter holes of a blast should be aligned with the principal joints. This alignment of perimeter holes will help produce a more stable excavation area whereas holes perpendicular to a main joint will tend to produce a ragged, unstable perimeter.

Bedding can also have an effect on both fragmentation and stability of the wall perimeter. Bedding planes or beds of weak material should be treated as zones of weakness. Stemming, rather than explosives, should be loaded in the borehole at the location of these zones. Dipping beds may cause stability problems and difficulty in fragmenting the toe area of the shot. Dipping beds and bed movement increase the likelihood of borehole cutoffs. The assistance of an explosive engineer may be requested for advice to insure adequate fragmentation and to offer advice to help minimize the unfavorable effects of both bedding and jointing.

BLAST DESIGN – BURDEN

The burden is defined as the distance from a borehole to the nearest free face at the instant of detonation. It is very important that the proper burden be calculated taking into account the borehole diameter, the density of the rock, the explosive and to some degree the length of the borehole. An insufficient burden will cause excessive flyrock and air blast. Too large a burden will give inadequate fragmentation, toe problems and excessive ground vibrations.

A general approximation for computing a burden distance is two times the borehole diameter in feet. For example, a 6 inch diameter borehole would require a burden of approximately 12 feet. A true burden distance will have to be developed by the blaster based on experience and mining conditions. This formula is only a general approximation and may not be exact. Adjustments can and may have to be made by the blaster.

Too small or too large a burden blast results may require the blaster to modify the burden formula and recalculate the burden for the next shot. A blaster should realize and always remember that the rock in a surface blast has only two places to go, toward the free face or upward. If a shot is detonated without a free face, the only possible movement is upward which always possesses a serious flyrock potential.

The burden dimension is a critical function of the borehole diameter. A second method, which is almost identical to the first method can be used to compute a burden distance. The second method is to multiply the borehole diameter by a figure ranging from 25 to 30, depending on field conditions and the material to be blasted. For example, a 6 inch diameter borehole multiplied by 25 would equal to 150 inches or 12 feet which is the same as multiplying a 6 inch borehole times 2 that is computed to be 12 feet also. A factor of 30 times the borehole diameter is commonly used when using denser products such as slurries or dynamites, which would in turn increase the burden distance. The burden-to-charge-diameter is seldom less than 20 and more than 40, even in the most extreme cases.

Flexing of the burden plays an important role in rock fragmentation. Small boreholes with a reduced burden breaks more easily than large boreholes with a large burden. The large borehole-burden ration results in stiffer burden.

A blaster must always remember that both of these methods used to compute a burden distance are only approximations. Minor adjustments usually required during field testing.

BLAST DESIGN – SPACING

Spacing is defined as the distance between adjacent boreholes, measured perpendicular to the burden. When one row of holes is blasted after the preceding row, the Spacing is measured between holes in a row. When the blast progresses on an angle to the original free face, the spacing is measured at an angle from the original free face.

Spacing is calculated as a function of the burden and also depends on the timing between the boreholes. Too close a spacing causes crushing between holes, flyrock, air blast, boulders in the burden and toe problems. Too wide a spacing causes inadequate fragmentation between holes, humps on the face and toe problems between holes.

Field experience has shown that the use of millisecond delays between holes in a row results in better fragmentation and also helps to reduce ground vibrations. A good first approximation of spacing distance is one and one-half times the burden distance. For example, a burden distance of 10 feet would have a spacing distance of 15 feet. When millisecond delays are used between holes in a row, the spacing-to-burden ration must be reduced to between 1.2 and 1.8, with 1.5 times the burden distance as a common approximation. Generally large diameter boreholes require lower spacing-to-burden ratios that range from 1.2 to 1.5 times the burden distance.

The proper spacing-to-burden ration must be determined by onsite experimentation and field testing using the preceding methods of computation as first approximations. The complexities of rock geology, interaction of delays, differences in explosive products, rock strength, and other variables will always force a blaster to conduct onsite experimentation and field testing to insure an efficient blasting program.

SECONDARY BLASTING

Secondary blasting is best described as the blasting of large boulders that are not adequately fragmented such that the boulders are too large to be handled efficiently by loading equipment. No matter how well designed and executed, some primary highwall blasts will leave boulders that are too large to be handled by equipment. Secondary fragmentation techniques must be used to break these boulders.

The loader operator will set aside boulders that are too large to handle efficiently. Secondary fragmentation can be accomplished in four ways: (1) A heavy breaking ball suspended from a crane may be dropped repeatedly on the boulder until breakage is complete. (2) A hole may be drilled into the boulder and a wedging device inserted to split the boulder. (3) Loose explosive may be packed into a crack or depression, covered with stemming or earth material and detonated. This type of charge is called mudcapping or adobe. (4) The most efficient method of secondary fragmentation is through the use of small boreholes (1 inch to 3 inch) loaded with explosives.

The adobe method of secondary blasting is inefficient because of a lack of explosive confinement with large amounts of explosives required. The common problems associated with adobe blasting is noise and flyrock, frequent inadequate boulder fragmentation and liability for accidental detonation. The adobe method is very dangerous because the primed charge, lying on the surface is prone to accidental detonation by external impacts from falling rocks or equipment. Extreme caution and special safety precautions must be used for an adobe blast to prevent excessive noise, flyrock and accidental detonation. The Virginia “Rules and Regulations” Governing Blasting in Surface Mining Operations will permit mudcapping or adobe only when a driller would be in a hazardous position while attempting to drill a boulder for secondary blasting.

The small borehole method of secondary fragmentation is the most efficient manner to break large, unbroken boulders. The small boreholes are directed toward the center of the mass of the rock. The holes are usually drilled two-thirds to three fourths of the distance through the boulder. Less explosive material is required to break a given amount of rock than in primary highwall blasting due to the availability of the free faces in all directions. One quarter pound of explosive material per cubic yard of rock directions. One quarter pound of explosive material per cubic yard of rock will usually do the job. The careful location of the explosive charge is more important that the precise amount. When in doubt, it is best to estimate on the low side and underload the boulder. It is best to drill several small holes to distribute the explosive charge rather than placing the entire charge in a single hole. All secondary blastholes should be stemmed. A special precautionary note for a blaster to always remember is that secondary blasts are usually more violent than primary highwall blasts. Any type of initiation system may be used to initiate a secondary blast.

Even though secondary blasting employs relatively small charges, their potential hazards must never be underestimated. Flyrock is usually more severe and more severe and more difficult to predict control than with primary highwall blasting. Secondary blasts require as many safety precautions in guarding as do primary highwall blasts. Blasting experience is an important key role to the success of secondary blasting.

PRESPLITTING

Presplitting or preshearing involves a single row of blastholes drilled along the intended excavation line. The Presplitting holes are usually the same diameter being in the two to four inch diameter range. The presplit holes are fired before any of the adjoining blast site explosive charges.

The theory of Presplitting is that radial cracks from the lightly shot boreholes will joint the radial cracks of adjacent holes thus assisting to help form a relatively smooth wall. This presplit crack will help to minimize or eliminate overbreak and help to produce a relatively, smooth wall.

Tubular watergel explosives are used as the main explosive charge in some Presplitting. Various cartridges are used to adapt to the borehole diameter. ANFO explosives are seldom used for Presplitting because of crushing around the borehole perimeter.

Where conditions prevent firing the presplit holes in advance of drilling the primary holes, Presplitting can accomplished by delaying the primary holes to allow the presplit holes to detonate first.

The best results for Presplitting are usually obtained by detonating the presplit holes before the primary holes are drilled.

Presplit holes are usually drilled with a close spacing pattern. The optimum spacing can best be determined by blaster experience and trial blasting.

The amount of stemming above the explosive column will vary on the formation and hole depth. In most cases, four to six feet will be adequate. The borehole should be blocked above the explosive column to prevent the stemming from filling in around the explosive column.

The depth that can be presplit at one time depends on the driller's ability to maintain good hole alignment. A small error from the proper drill angle causes a deviation in the borehole alignment. This deviation becomes even more as the hole depth increases.

Presplitting holes are usually initiated only one shot in advance of the primary blast.

UNIT VI

ELECTRIC BLASTING

ELECTRIC BLASTING

CIRCUIT WIRING

Electric blasting, with such assets as delay caps, CD blasting machines and sequential timers, has made it possible to fire a large number of caps in a predesigned sequence with precise control over the time of firing. An understanding of the basics of electrical circuitry is essential in order to conduct safe and successful electrical blasting.

Four general principles are required to conduct safe and successful electric blasting: (1) Proper selection and layout of the blasting circuit. (2) An adequate blasting machine. (3) Recognition and elimination of electrical hazards. (4) Good electrical connections, circuit balancing and circuit test.

The type of circuit will depend on the number of electric blasting caps to be fired. A series circuit is used on small blasts with a limited number of detonators. A series in parallel is used where a large number of caps are involved. Parallel circuits are usually limited to tunnel and shaft sinking operations. Each of these three types of circuits will be discussed later.

Recognition and elimination of electrical hazards must be the first consideration before designing any blast that will use an electrical system. These hazards include stray current, lightning, static electricity, RI energy, and induced electrical current.

A serious lack of attention to details is the most frequent cause of explosive accidents. All electrical connections must be tight, clean, and insulated from the earth. Extreme caution must be taken to prevent damage to legwire insulation, both on the surface and inside boreholes. All firing lines must be tested before each and every blast.

Resistance, measured in ohms, is a major property of all electrical circuits. All substances have resistance. Resistance is the opposition to the flow of electrical current. Copper wire, such as detonator legwires, has a very low resistance and thus are good conductors of electricity. Materials like plastic have high resistance and thus are classified as insulators.

Resistance is the property that will determine how much current will flow through an electrical blasting circuit. Electrical measuring devices such as a blasting galvanometer, blaster's ohmmeter, and a blasting multimeter are used to measure the resistance of blasting circuits. An electrician's volt-ohm meter must never be used to test any electrical blasting circuit.

The blaster in charge must know how to compute, test, measure and troubleshoot an electrical blasting circuit. Detonator legwire resistance, complete circuit resistance and firing line resistance must be computed and compared to the calculated resistance. These computations are required to determine if a designed blast can be initiated with the applicable blasting machine.

A thorough understanding of ohms law is required to make these computations. Ohms law: E = I x R, E represents voltage (supplied by the blasting machine), I represents the current that will flow through the circuit, R represents the resistance of the circuit. For example: a blasting machine can deliver 100 volts, the circuit resistance is 50 ohms, then the current flow will be 2 amps.

Successful simultaneous initiation of a large number of electric detonators requires delivery of sufficient current to all detonators within a few milliseconds. The time required to heat the bridge wire in an electric detonator to a temperature that will cause burning of the ignition charge is a direct function of the current. The bridge wire in commercial electric detonators requires 1.5 amps for reliable initiation. The bridge wire heats up very quickly and rapidly transfers heat to the ignition mix. Heat energy delivered to a bridge wire over a time interval of more than 10 milliseconds is not as efficient in heating the bridge wire as the same amount of energy delivered in a few milliseconds.

It is of vital importance of delivering sufficient current to all detonators in the circuit within a few milliseconds. At low current levels, slight differences from one detonator to another can result in large variations of initiation times. In series circuits, this can result in one detonator firing prior to firing of all detonators. This fast firing of one detonator cuts off the flow of current before all detonators have been initiated and results in failure of one or more detonators.

As has been said before in this text, the internal construction of electric detonators manufactured by different companies varies considerably. As a result, different brands of detonators are absolutely not compatible in the same blasting circuit. Electric detonators of different manufacturers must never be used in the same blasting circuit. This practice is almost certain to cause a partial or complete misfire.

Explosive manufacturers do not recommend the use of instantaneous and delay detonators in the same electric blasting circuit.

DETONATOR LEGWIRE RESISTANCE

The resistance of a detonator is primarily determined by the legwires. Most detonator legwires are made of copper which is a good conductor. The longer the legwire length, the greater the resistance will be. The resistance of detonator legwires should always be measured with a galvanometer and compared to the manufacturer rate resistance. If any detonator does not read a close comparison then it should never be used.

A single detonator requires .5 amp minimum firing current with a direct current power source to overcome the resistance of the detonator in order to fire. Any series will require 1.5 amps of current with a direct current power source per series to properly fire the circuit.

The applicable detonator manufacturer should always be consulted to determine both the minimum and maximum safe firing current.

Electric detonator legwire resistance shall never be measured with an electrician's volt ohm meter. This type meter can supply sufficient current to fire the detonator.

The shunts provided on the free end of detonator legwires should never be removed except when testing for resistance and continuity. After testing, the legwires should be shunted back together.

CONNECTING LINE RESISTANCE

Connecting wires are used to connect holes or to connect individual series to the firing line. Connecting line is usually #16 to #20 AWG or heavier wire. The connecting line should never be smaller than a #20 AWG size. You must remember, though, that the increase in AWG number size is opposite to the size of wire. A size #20 AWG wire is smaller than a #10 AWG size wire.

Connecting line has solid copper, conductor wire, and a tough, waterproof insulation. Connecting lines are always subjected to damage by the blast.

Always remember - - never reuse connecting wire.

The twisted loop splice is commonly used to splice detonator legwires to connecting lines.

The wrap around splice is commonly used to splice connecting line to a firing line.

The connecting wire has resistance just as does detonator legwires. Connecting wire resistance must be computed and calculated as an integral part of the total resistance of a blasting circuit.

Connecting wire resistance is rated in "ohms" per 1000 feet. For example, a #20 AWG copper wire has a resistance 10.15 ohms per 1000 feet. The resistance of connecting line can be calculating by using the formula $RC = \text{length of connecting wire} \times \frac{10.15}{1000}$. 200 feet of #20 AWG connecting wire would have a calculated resistance of 2.03 ohms. As can be seen from this formula, the longer the amount of connecting wire used, the higher the amount of resistance.

A blaster should always consult with the detonator manufacturer with questions and or problems of connecting line with any applicable electric blasting system.

FIRING LINE RESISTANCE

A firing line is used to connect the detonator circuit to the blasting machine. Firing lines are usually made with a solid-core, copper conductor that has a tough waterproof insulation. The recommended size for series and series-parallel circuits of normal size is #10 to #14 gauge. The firing line should never be smaller than a #14 gauge wiring size. The same principle of wire size also applies to firing line in that the larger the number of size wire, the smaller the wire.

Standard wire should never be used for a firing line because individual strands may break due to flexing during rolling and unrolling before and after blasts. These broken strands would reduce the current carrying capacity of the firing line that would not be readily detectable with a test instrument.

Duplex wire, both solid core and stranded, are not recommended for a firing line. The thin insulation barrier between the conductors can crack or break down due to physical abuse and would not be detectable by visual inspection. Capacitor discharge blasting machines could damage this insulation and cause arcing between the conductors due to the voltage generated by the machine.

Firing line resistance is rated in "ohms" per 1000 feet. For example, #14 AWG copper wire has a resistance of 2.53 ohms per 1000 feet. The resistance of firing line can be calculated by using the formula RF = 2 times length of firing line X $\frac{2.53}{1000}$. if 500 feet of firing line was used for each side of the blast circuit, then the calculated resistance would equal 2.53 ohms. As can be seen from this formula, the longer the firing line used, the higher the resistance.

A firing line must be tested for continuity before every blast with a blaster's multimeter or blaster's galvanometer. It should always be replaced when there is any evidence of physical damage to the insulation. After the firing line is laid out, it should be checked again with a blaster's multimeter or blaster's galvanometer for continuity. The firing line should also be visually inspected for cuts and abrasions of insulation.

The firing line should never be laid out until the blast circuit is completely wired and all unnecessary personnel have been removed to a safe location. The blasting machine end of the firing line must always be shunted before the other end is connected to the blasting circuit. The resistance of the entire circuit should be tested with a blaster's multimeter or blaster's galvanometer after the final connects have been completed.

The calculated resistance of the entire circuit must always agree with the readings on the meter or no attempt should be made to fire the blast. If proper readings are not obtained, reshunt the firing line before returning to the blast area to locate and correct the trouble source. Never allow the bare ends of any part of the blasting circuit or firing line to come in contact with the ground or any metal object. When the meter readings confirm the calculated resistance, the blasting machine and firing line can be connected for firing. The blasting machine shall always be under direct control of the blaster in charge and the firing line connection to the blasting machine shall always be authorized and controlled by the blaster in charge.

All personnel that are not involved in inspecting and testing the firing line should be removed from the area.

The resistance of the firing line must always be tested twice. It should be tested in the "open" position and the "shunted" position.

The "open" position test: (1) Separate the bare ends of the firing line at both ends. (2) Touch the ends of one end to the galvanometer terminals. The galvanometer needle should not move. If the needle moves, a short is present that a blaster must correct before using.

The "shunted" position test: (1) Shunt the bare wire ends at one end of the firing line. (2) Touch the bare wires at the other end to the terminals of a galvanometer. The galvanometer needle should not move to the calculated resistance of the firing line. If the needle does not move, a break is present in the wire that a blaster must correct before using.

A total resistance and continuity test must be preformed of the entire circuit with a blaster's galvanometer, blaster's multimeter or blaster's ohmmeter. The tested resistance must equal the calculated resistance. A very low resistance would indicate a short circuit. A very high resistance would indicate an open circuit. Both a very low or very high resistance indicates a problem that must be corrected before any attempt is made to fire the blast.

SERIES CIRCUIT

The series circuit is the first of three electrical blasting circuits that will be discussed in this guide. A single series of electric detonators are connected in a line such that the current from the blasting machine has only one path to follow with the same amount of current flowing through each detonator.

The series circuit is commonly used when a small number of electric caps will be detonated. Most manufacturers recommend that the number of detonators wired in a single series should not exceed fifty (50). Detonators with long legwires would reduce this total number of caps that could be wired in a single series.

A main point to always remember about a single series circuit is that a break in any part of the circuit will stop the current flow through the entire circuit.

Each detonator in a series circuit has a resistance as does the connecting line and firing line. The total resistance of a series circuit is the sum of all the circuit resistance. The manufacturer specifications will rate the resistance of each detonator according to legwire length. The blaster should add the resistances of the total number of detonators and compare to the manufacturer specifications.

The resistance of a series circuit is the easiest of the three electric blasting circuits to calculate. When all detonators in the series circuit have the same resistance, the total resistance of one detonator by the total number of detonators. When detonators in a series circuit have different resistance, then the total detonator resistance is computed by adding the resistance of all the detonators.

Series problem example: 10 electric detonators with a resistance of 2 ohms each are wired in a single series. The total resistance is calculate by multiplying 10 times 2 which equals 20 ohms.

Series problem example 10 electric detonators with the following resistance values, 1.8 ohms, 1.9 ohms, 2 ohms, 2.1 ohms, 2.2 ohms, 2.3 ohms, 2.4 ohms, 2.5 ohms, 2.6 ohms, and 2.7 ohms. The total resistance is calculated by adding the resistance of all the detonators which equals 22.5 ohms.

The total resistance of a series circuit is calculated by adding the detonator resistance, connecting wire resistance and firing line resistance. The current flow through each detonator is calculated by dividing the output voltage of the blasting machine by the total resistance of the complete circuit. The minimum recommended firing current through each detonator in a single series is 1.5 amps DC or 2.0 amps AC. The blaster should always consult with the detonator manufacturer to confirm this minimum firing current.

Series problem: Assume a series circuit of 20 detonators with 40 fee copper legwires that have a resistance of 1.8 ohms each will be used. 300 total feet of #20 copper connecting line with a resistance of 10 ohms per 1000 feet will also be used. 600 feet of #12 copper firing line with a resistance of 1.6 ohms per 1000 feet will be used on each side of the blasting circuit. The total length of the firing line would be 1200 feet. The direct current CD blasting machine will deliver 100 volts.

Step 1: Determine the resistance of the cap circuit by using the formula:
Resistance of cap circuit = number of caps x resistance of each cap.

R = 20 x 1.8

R = 36 Ohms

Step 2: Determine the resistance of the connecting line by using the formula:

$$R = \frac{\text{LENGTH OF WIRE X RESISTANCE OF WIRE PER 1000 FEET}}{1000}$$

$$R = \frac{300 \text{ X } 10}{1000}$$

R = 3 Ohms

Step 3: Determine the resistance of the firing line by using the formula:

$$R = \frac{2 \text{ x Length of Wire x Resistance of Wire per 1000 feet}}{1000}$$

(Length of firing line for each side of circuit – 600 feet)
(Total length of firing line – 600 x 2 = 1200 feet)

$$R = \frac{1200 \text{ x } 1.6}{1000}$$

R = 1.92 Ohms

Step 4: Determine the total resistance of the blasting circuit.

Use the formula:

Total Resistance = Cap Resistance + Connecting Wire

Resistance = 36 + 3 + 1.92

R = 40.92 Ohms

Step 5: Determine if the blasting machine can supply sufficient voltage to deliver the proper current to fire the circuit. You must remember that each detonator fired by a direct current blasting machine must be supplied with at least 1.5 Amps.

Use Ohms law ($E = I \times R$, $I = \frac{E}{R}$) to determine if the proper

current can be delivered to the blasting circuit.

3. $I = \frac{E}{R}$

I equals current

E equals voltage capacity of the blasting machine

R equals total resistance of the blasting circuit

$I = \frac{E}{R}$

$I = \frac{100}{40.92}$

I = 2.44 amps

Sufficient current is available to fire this circuit.

SPECIAL NOTE: If the detonators have different resistances, then the total resistance of the detonator circuit is the sum of the resistance of all the detonators.

PARALLEL CIRCUITS

Parallel circuits are most commonly used when sinking shafts and constructing tunnels. A parallel circuit by itself is usually not used in surface mining. This circuit is difficult to check for continuity because the total resistance is so small that it will read so close to zero resistance on the measuring instrument, whether it be a blaster's galvanometer, blasting multimeter or blaster's ohmmeter.

A parallel circuit will provide more than one path through which the current can-travel to the blasting machine or sequential timer. A break in one part of the circuit will not stop the flow of current to other parts of the circuit. The resistance in a parallel circuit may be different from one branch to another. Each branch in a parallel circuit will receive a separate and distinct current. These variations of a parallel circuit will make it extremely difficult to calculate a total detonator circuit resistance. Parallel circuits require a higher current flow than series or series-parallel because each parallel branch requires its own current supply.

Two "buswires" are used to hook to each side of the detonator legwires. These buswires are usually 10to 14 gauge, solid core, copper wire. Aluminum wire is not recommended for this circuit.

Four basic forms of parallel circuits are available but the “closed loop, reverse” hook-up provides the most balanced and even current flow. Large parallel blasts require very high output to calculate the total resistance of a parallel circuit. The four resistances include: (1) detonator resistance, (2) buswire resistance, (3) connecting line resistance, (4) firing line resistance.

The detonator resistance in parallel circuits may be balanced or unbalanced. The balanced circuit is when all the detonators have the same resistance, which is most common. The unbalanced circuit is when the detonators have a different resistance. Every detonator will not receive the same amount of current in an unbalanced parallel circuit. Because of the complexity of computations in an unbalanced parallel circuit and rare use in surface mining, the detonator-explosive manufacturer should be consulted for expert assistance. Therefore the unbalanced parallel circuitry will not be covered in this study guide.

In a balanced parallel circuit, the total resistance of the detonator circuit is computed by dividing the number of detonators into the resistance of one detonator. For example, 40 detonators with a resistance of 2 ohms each are to be used in a parallel circuit. The total detonator resistance would be 2 divided by 40 which equals .05 ohms. As you can see, this would be a difficult measurement to make because it is so small.

Two types of current should be calculated in a parallel circuit, the total firing line current and the branch or detonator current.

An example for computing total firing line current: A balanced, parallel circuit has 20 detonators and the total circuit resistance including detonators, buswires, connecting line and firing line is 5 ohms and will be fired with a 200 volt blasting machine.

$$\text{Line Current} = \frac{\text{Voltage of blasting machine}}{\text{Total circuit resistance}}$$

$$\text{Line Current} = \frac{200}{5}$$

Line Current = 40 amps

An example for computing branch or detonator current: From the same circuit above, 20 detonators wired in a parallel circuit have a total firing line current of 40 amps.

$$\text{Branch or Detonator Current} = \frac{\text{Line Current}}{\text{Number of Detonators}}$$

Branch I = 40

Branch I = 2 amps

As can be seen, the sum total of the individual branch currents will always be equal to the total, firing line current.

Parallel problem: Assume a balanced parallel circuit of 30 detonators with a resistance of 3 ohms each will be used. 200 feet of #12 copper buswire with a resistance of 1.6 ohms per 1000 feet will be used. 300 feet of #16 copper connecting line with a resistance of 4 ohms per 1000 feet will be used. 400 feet of #10 copper firing line with a resistance of 1 ohm per 1000 feet will be used. The direct current blasting machine will deliver 200 volts.

Step 1: Determine the resistance of the cap circuit

Use the formula = $\frac{\text{Resistance of one cap}}{\text{Total number of caps}}$

Detonator (cap) Resistance = $\frac{3}{30}$

Detonator (cap) R = .1 Ohm

Step 2: Determine the buswire resistance

Use the formula: $\frac{.5 \times \text{length} \times \text{resistance per 1000 feet}}{1000}$

Buswire Resistance = $\frac{.5 \times 200 \times 1.6}{1000}$

Buswire Resistance = .16 ohms

Step 3: Determine the connecting wire resistance

Use the formula: $\frac{\text{Length} \times \text{Resistance per 1000 feet}}{1000}$

Connecting Wire Resistance = $\frac{300 \times 4}{1000}$

Connecting Wire Resistance = 1.2

Step 4: Determine the firing line resistance

Use the formula: $\frac{2 \times \text{Length} \times \text{Resistance per 1000 feet}}{1000}$

Firing Line Resistance = $\frac{2 \times 400 \times 1}{1000}$

Firing Line Resistance = $\frac{800}{1000}$

Firing Line Resistance = .8

Step 5: Determine the total circuit resistance

Add the detonator (cap) resistance, buswire resistance, connecting line resistance and firing line resistance:
Detonator Resistance = .1 ohm
Buswire Resistance = .16 ohm
Connecting Wire Resistance = 1.2 ohms
Firing Line resistance = .8 ohms
Total Circuit Resistance = .1 + .16 + 1.2 + .8 = 2.26 ohms

Step 6: Determine the total, firing line current Use the Ohms law formula: $I = \frac{E}{R}$

I = Line Current

E = Voltage capacity of blasting machine – 200 volts

R = Total circuit resistance

$$I = \frac{E}{R}$$

$$I = \frac{200}{2.26}$$

I = 88.5 amps

Step 7: Determine the branch current or detonator current

Use the formula = $\frac{\text{Total Line Current}}{\text{Number of Branches (or detonators)}}$

$$\text{Detonator Current} = \frac{88.5}{30}$$

Detonator Current = 2.95 amps

1 amp is the minimum recommended direct current for each detonator in a parallel circuit. 10 amps is the maximum recommended direct current for each detonator in a parallel circuit.

SERIES IN PARALLEL CIRCUIT

The series in parallel circuit is the most common type of circuit used in surface blasting. The main advantage of the series in parallel circuit is the large number of detonators which can be fired from a blasting machine without a large voltage capacity. The series in parallel circuit is commonly used to fire a large number of detonators.

The individual series are wired in parallel with the other series in a series-parallel circuit. Each series should contain the same number of detonators or the same resistance to assure even current distribution. This type circuit is used when the total number of detonators exceed 40 to 50. each individual series should not contain more than 40 detonators and or a maximum resistance of 100 ohms. Each series should also be balanced within plus or minus 2 ohms. The number of electric detonators in each series should be reduced when current leakage is a problem.

The total firing line current will divide in each series in a series-parallel circuit. The resistance of each series should be the same or nearly the same as each of the other series. Minor differences of one or two detonators will not materially affect the results of the blast. This series-balancing will insure that the firing line current will be divided equally into each series. The reverse hook-up between the firing line and connecting line will also help to insure equal current distribution to each individual series.

For any set of conditions, there is an optimum number of series to obtain the maximum current through each series of a series-parallel circuit. The current will be low because the resistance will be high when too small a number of series are used. The current per series will be low when too many series are used because the total line current is split too many ways. The minimum direct current required for each series is 1.5 amps when delay detonators are used. The minimum direct current for each series is 2 amps when delay and instantaneous are used in the same blast. For this reason, explosive manufacturers do not recommend using instantaneous and delay detonators in the same blast.

Buswires are sometimes used to connect individual series in parallel. This buswire use may result in an uneven current distribution and could cause failure in one or more series. If absolutely necessary to use buswires, the resistance of one buswire should not exceed the total resistance of detonators divided by 1000.

Series in parallel problem: Assume a series in parallel circuit has 8 series with 15 detonators in each series. Each detonator has a resistance of 2.2 ohms. 400 total feet of #18 copper, connecting line with a resistance of 6 ohms per 1000 feet will be used. 600 feet of #12 copper firing line with a resistance of 2 ohms per 1000 feet will be used. The total length of the firing line would be 1200 feet. The direct current CD blasting machine will deliver 200 volts.

Step 1: Determine the resistance of each series cap circuit
Use the formula: Number of caps x resistance of each cap
Series Detonator Resistance = 15 x 2.
2 Series Detonator = 33

Step 2: Determine the total circuit, detonator resistance

$$\text{Use the formula} = \frac{\text{Resistance of 1 series}}{\text{Number of series}}$$

$$\text{Total circuit detonator resistance} = \frac{33}{8}$$

Total circuit detonator resistance = 4.13

Step 3: Determine the connecting line resistance

Use the formula =

$$R = \frac{400 \times 6}{1000}$$

$$R = \frac{2400}{1000}$$

R = 2.4

Step 4: Determine the firing line resistance

Use the formula:

$$\frac{2 \times \text{length of wire} \times \text{resistance of wire per 1000 feet}}{1000}$$

$$R = \frac{2 \times 600 \times 2}{1000}$$

$$R = \frac{2400}{1000}$$

R = 2.4

Step 5: Determine the total resistance of the blasting circuit

Use the formula:

Total resistance = Cap resistance + Connecting wire resistance + Firing line resistance

R = 4.13 + 2.4 + 2.4

R = 8.93

Step 6: Determine the total firing line current

Use the formula:

$$\text{Firing line current} = \frac{\text{Blasting machine voltage capacity}}{\text{Total circuit resistance}}$$

$$\text{Firing line current} = \frac{200}{8.93}$$

Firing line = 22.40 amps

Step 7: Determine the series firing current

Use the formula:

$$\text{Series Firing Current} = \frac{\text{Total line current}}{\text{Number of Series}}$$

$$\text{Series Firing Current} = \frac{22.40}{8}$$

Series Firing Current = 2.8 amps

2.8 amps will be distributed to each of the 8 series and 2.8 amps will be delivered to each detonator.

The following minimum and maximum current requirements to fire electric detonators should always be remembered. These requirements should be confirmed with the appropriate explosive-detonator manufacturer.

Direct current power source:

Single detonator = .5 amp per detonator (minimum)

Single series = 1.5 amps per series (minimum)

Series in parallel = 1 amp per detonator (minimum)

10 amps per detonator (maximum)

Alternating current power source requirements will not be discussed because they are not commonly used in surface mining. Consult with the appropriate detonator manufacturer for advice on AC power source requirements.

WIRING SPLICES

Wiring splices are a vital element of successful and safe electric blasting practices. Lack of attention to details such as splices are a frequent cause of electrical circuit misfires that could result in fatal or serious injury and costly damage. All electrical connections must be tight, clean, and insulated from the ground. Caution must be taken to prevent abrading or stripping legwire insulation inside boreholes or on the surface. All electric blasting circuits should be inspected and tested prior to every blast.

The reliability of every electric blasting circuit depends on the number and quality of splices in that circuit. The quality of splices are as important as any other critical factor in good blasting practices. Strong and reliable splices should be made to prevent current leakage. A strong, secure splice will help to prevent "shorting out" of electrical circuits.

The twisted loop splice is the best way to splice two wires of similar size in a blast circuit, such as detonator legwires. When splicing a tight gauge legwire to a heavier gauge wire, the lighter gauge wire is wrapped around the heavier gauge wire. Both methods of splicing are easy, quick to make and are strong, reliable splices. Both types of splices are also easy to disassemble if a circuit has to be taken apart. Both types of splices provide a strong and reliable connection. The following factors will help to prevent current leakage and "shorting out" of detonator legwires: (1) The splices should be insulated with electrical tape. (2) Propping up the splices on boxes or dry cardboard when the splices are not insulated with electrical tape. (3) Staggering the locations of splices. Detonator legwires can be twisted together four inches from a splice to absorb induced strain on a splice and help prevent wire connections from pulling apart.

Extreme care and caution is absolutely necessary in the wiring and testing of an electrical blasting circuit to prevent the potential of a misfire.

SERIES BALANCING

Electrical blasting circuits that contain only a small number of detonators are usually connected in a single series circuit. When a large number of detonators are used, according to blast site wiring practices, a series parallel circuit should be used. Each series of the series-parallel circuit should be balanced to insure that the firing current is equally divided into all series. The resistance of each series should be checked and balanced within plus or minus 2 ohms with 100 ohms maximum in each series. This check should be made with a blasting galvanometer or blasting multimeter. An electrician's volt-ohm meter should never be used for conducting this test or any other test on an electric blasting circuit.

The formula of product divided by the sum can be used to calculate an unbalanced series-parallel circuit. For example: A blasting circuit has 4 series. Series 1 has a total resistance of 16 ohms. Series 2 has a total resistance of 14 ohms. Series 3 has a total resistance of 12 ohms. Series 4 has a total resistance of 10 ohms. Series 1 and series 2 is used in the first calculation. The product of 16 and 14 is 224. The sum of 16 and 14 is 30. 224 divided by 30 is 7.5.

The figure of 7.5 and series 3 is used in the second calculation. The product of 7.5 and 12 is 90. The sum of 7.5 and 12 is 19.5. 90 divided by 19.5 is 4.6.

The figure of 4.6 and series 4 is used in the last calculation. The product of 4.6 and 10 is 46. The sum of 4.6 and 10 is 14.6. 46 divided by 14.6 is 3.15. 3.15 ohms is the total resistance of this circuit. The total resistance of this type circuit will always be less than the resistance of any series.

In a balanced series-parallel circuit when each series is the same, the resistance of one series divided by the number of series will equal the total resistance of the circuit. For example: A series-parallel circuit has 6 series with a resistance of 96 ohms in each series. The total resistance is 96 divided by 6, which is 16.

CURRENT LEAKAGE

Current leakage is the loss of part of the firing current through the ground which bypasses a portion of the electric blasting circuit. Detonator failure and misfires are likely to occur unless this condition is recognized and prevented.

The amount of current loss is determined by many factors and the main factor is the conductivity of the rock. Leakage can occur in nonconductive rock if the ground is wet. Moist ANFO and watergels are conductive and will permit current leakage if the detonator legwires are damaged inside a borehole.

When electric detonators are wired properly into a series or series parallel circuit and sufficient firing current is provided, but some of the detonators fail to fire, the chances are good that part of the current bypassed the unfired detonators. The detonators misfire because the current they receive is not sufficient to activate their ignition system before other detonators that receive a higher firing current detonate and interrupt the series circuit. Bare splices touching the ground or damaged legwire insulation will result in detonator, firing current bypass through the earth or conductive material.

The following conditions will most likely contribute to current leakage: (1) Ragged boreholes that damage legwire insulation. (2) Wet or damp ground. (3) Highly conductive earth medium. (4) Water in the borehole. (5) Poured or pumped slurry loaded in a borehole. (6) Failure to insulate bare wires at splices from the ground and from each other. If one or more of the above conditions are present, a current leakage test should be made while assisted by an explosives manufacturer consultant.

Two basic general rules should be followed when electric blasting: (1) The power source or firing unit must be capable of firing the number of detonators in the circuit. (2) The individual series in a series-parallel circuit should be balanced to within plus or minus 2 ohms.

In order to provide the minimum recommended firing current, the number of detonators per series can be reduced. This will reduce the resistance of each series and thus the circuit. Total circuit resistance can also be reduced by using a heavier gauge firing line or using two conductors for each side of the firing line. Firing line resistance can have a very significant effect on the firing current that is delivered to each detonator.

When conditions that cause current leakage are known prior to blast preparation, the following steps can be taken to reduce the possibility of current leakage: (1) Use care n loading boreholes to reduce the chance for damaged legwire insulation. (2) Make sure all connections do not touch the ground. (3) Avoid the use of splices in the borehole. (4) Use a blasting machine that will supply sufficient firing current to fire the detonators. (5) Always stay well below the maximum number of detonators that the blasting machine is capable of firing under normal field conditions. (6) Use heavier gauge firing lines to supply more energy to the blasting circuit. (7) Reduce the connecting wire resistance when possible by shortening its length and or using a heavier gauge wire.

The capacitor discharge blasting machine offers the safest, most dependable, and economical source of energy for electric blasting. Successful electrical blasting depends on four general principles: (1) Proper selection and layout of the blasting circuit. (2) An adequate blasting machine that is capable of delivering sufficient firing current. (3) Recognition and elimination of all electrical hazards. (4) Circuit balancing, good electrical connections and complete circuit testing.

ARCING

Arcing is best described when the magnitude and duration of firing current delivered to an electric detonator cannot be dissipated. Electric detonators can be damaged if too much electrical energy is applied. This excessive firing current will generate excessive heat that usually results in an electrical arc.

Under normal firing current conditions, the amount of heat produced is easily dissipated. When excessive firing current is applied for too long a time duration such that the heat cannot be dissipated, arcing will occur.

Arcing will cause the following: (1) Erratic timing both fast and slow of delay detonators that will result in unsatisfactory results. (2) Shell rupture. (3) Holes burned in detonator shell. (4) Ejection of detonator sealing plug. (5) Hangfire or misfire.

A parallel, electric detonator circuit presents a very high risk for an arcing malfunction. The high risk of arcing in the parallel circuit is caused by the amount of current delivered to each detonator.

Some brands of electric detonators contain a special semi-conductive plug in the bridgewire assembly that will short out and provide a low resistance path for excessive firing current. This special assembly will help eliminate internal arcing and minimize the amount of heat generated.

The following procedures should be followed to help prevent arcing: (1) the detonator manufacturer should be consulted on the maximum safe current that can be applied to any detonator. (2) Special precautions must be taken when firing a parallel circuit. (3) Capacitor discharge blasting machines will help to prevent arcing, provided that the blast circuit does not exceed the rating of the machine.

BLAST CIRCUIT CHECKS

Blast circuit checks are a vital element of any successful electric blasting program. Different types of checks must be performed to insure a safe and efficient circuit. A sufficient time should be allowed after all circuits are wired up and before firing the blast to check the blasting circuit.

Two types of checks should always be made. Electrical checks and a visual check should always be made. Electrical checks include: (1) The resistance of each detonator should be checked with a blasting galvanometer before it is assembled into a primer. (2) The resistance of each detonator should be checked again after the borehole is loaded. If any detonator shows an open or short circuit, it should never be used. An additional primer can be placed on top of the explosives column before the stemming is inserted if a detonator shows an "open" circuit after the explosive column is in place. (3) The resistance of each detonator should be checked again after the stemming is added so that additional boreholes will not be loaded until the problem detonator borehole is taken care of. (4) Each series of detonators should be checked to be sure the resistance is as calculated, that the series are balanced and that all series have about the same resistance. If blasts contain more than one series as in a series-parallel resistance. If blasts contain more than one series as in a series-parallel circuit, the total resistance will always be less than the resistance of any one series. For example, a series-parallel circuit has 4 series. #1 series – 20 ohms, #2 series – 18 ohms, #3 series – 16 ohms. #4 series – 14 ohms. The total resistance of this blast circuit is 4.18 ohms. (5) The firing line should be checked for an open or short circuit before it is connected to the detonator circuit. The two conductors at one end should be connected, and tested at the other end with a blasting galvanometer. The firing line resistance should be equal to the measurement with the galvanometer. The two conductors of the firing line should now be opened and the galvanometer should read infinite ohms at the other end. If a high, low, unstable or if other than infinite ohms is read when the conductors are separated, then the firing line should not be used until it is inspected for damage, defective insulation and or broken conductors repaired. If there is any question about the continuity, condition, or quality of the firing line, then it should be discarded and a new firing line obtained. The firing line should be inspected for damage after each blast.

A visual check should always be made of all blasting circuits. The visual check is made by walking the shot while tracing each series to make sure that all detonators are wired into the circuit, that all splices are intact, out of water and insulated from earth. All unused explosives must be removed from the blast site. All unnecessary personnel should be removed from the blast site so as to prevent problems with the wiring circuitry. The blaster in charge should walk the entire shot and should never allow unnecessary personnel to walk in the shot area.

A blaster should always remember that electrical checks of any blasting circuit shall never be done with an electrician's volt-ohm meter.

UNIT VII

EXTRANEOUS ELECTRICITY

EXTRANEOUS ELECTRICITY

STRAY CURRENT

Stray current is defined as current flow outside an insulated conductor system. Unwanted electrical energy that may enter a blasting circuit must be kept at safe levels or excluded altogether. This electrical hazard can cause premature detonations in either an electric or nonelectric blasting system. A very thorough evaluation for stray current and other sources of extraneous electricity should be made at blasting sites before any explosives are brought into the area.

In order to understand the potential hazard of stray current and other sources of extraneous electricity, a blaster must have a basic knowledge of the theory of electricity. The theory of electricity is that electric current that flows through power lines to electrical equipment from a battery, generator or power station transformer will always seek to return to its generated source by all available paths. These source return paths will include: (1) conductors insulated from ground such as electrical cables (2) conductors not insulated from ground such as pipelines, and other metal objects (3) the earth itself. When the return conductor between the area of use and the source location is interrupted, the current will seek to find another path and dangerous ground stray current may result. When this stray ground current has a means to enter a blasting circuit, a dangerous condition is present. This stray current could be sufficient to heat the "bridge wire" of a detonator and result in a premature detonation. This hazard can be minimized if continuous metal objects are kept away from the vicinity of electric blasting circuits. Also, stray current measurements should be conducted before electric blasting caps are to be used in a particular location.

In order to better understand the extraneous electricity and stray current hazards, some facts about extraneous electricity must be understood and remembered. The accepted "safe" level of extraneous electricity for electric blasting is derived from t he current level required to detonate electric blasting caps. The minimum firing current for commercial electric blasting caps presently manufactured in the United States is approximately .25 amps. IME has established the maximum "safe" current permitted to flow through an electric blasting cap without the hazard of detonation is .05 amps, which is one-fifth of the minimum firing current. Electric blasting must not be conducted in areas where extraneous currents are greater than .05 amps. Operators that use electric blasting caps should measure for extraneous currents in the blast area at frequent intervals to insure they are kept at a safe level. The internal resistance of most extraneous currents is usually high enough to limit the current to a few milliamps, therefore electrical blasting can be safely conducted in normal field conditions.

When extraneous currents such as stray current exceeds .05 amps, the source of current must be traced and eliminated before electric blasting caps can be used safely. If the source of current cannot be traced and eliminated, then a nonelectric system of initiation must be used.

Other sources of possible stray current include electric fences in the blast area, metal fences, machinery housings, a conductive rock strata that lies between two nonconductive strata's and any other object in context with a defective insulated electrical source. A potential hazard exists if an electric detonator becomes a part of one of these alternate conductive paths.

Generally, in properly grounded and maintained electric circuits, stray current sufficient to detonate electric blasting caps is rarely found, because the resistance of the earth is usually high and the potential between two points close together is usually low. However, dangerous stray current can be found when electric blasting legwires contact separate conductive strata. This is why extreme care and caution must always be taken to prevent damage and abrading of detonator legwires. Hazardous currents, more than .05 amps can also reach electric blasting caps if the legwires contact pipelines and other metal elongated objects. The earth offers such a large cross-section to extraneous current that even the high resistance earth will draw currents out of ground conductors and other sources of electrical energy. Power and lighting circuits should be kept away from the blasting area during explosive loading operations. Isolation of all electric blasting wiring from the earth and from possible current carrying conductors are additional measures that should be taken to reduce the potential hazards of stray current.

Stray current measurements should be made over a sufficient period of time to determine if stray current is present when equipment is started and operated in the test area. Electric blasting in highly conductive ground or earth, in highly metallic rock formations, in wet areas, and blast operations near electric distribution facilities will warrant frequent tests for the presence of hazardous stray current.

The following safety procedures should be observed to help minimize the probability of stray current:

(1) If an electrical power distribution system and or electrically operated equipment is located near a blasting site, then periodic checks of the wire and insulation should be made to insure it is maintained in good condition;

(2) All metal objects, pipes, framework of metal housings, etc. should be provided with a low resistance ground to earth;

(3) Remove all possible potential sources of stray current such as powerlines, lights, electric equipment batteries, etc. from the blast area prior to the loading of explosives;

(4) Known stray current sources located near a blast area should be deenergized and locked out when explosive materials are present;

(5) Do not remove shunts from detonator legwires except for continuity testing, after which they should be reshunted, and kept shunted until when trying them into the blast circuit. Always keep all free ends of blast wiring circuits shunted together except when firing the shot;

(6) Insure that all splices are insulated from the earth or ground and other potential stray current sources. Always use a well insulated firing line that is not damaged and is not near any possible source of stray current.

Taking into consideration that approximately 70 million electric blasting caps are used annually in the United States, a remarkable safety record has been compiled in the use of electric blasting caps. This safety record has been established by three basic electric blasting fundamentals: (1) Knowing and observing the basic fundamentals of good blasting safety practices (2) Devoting diligent attention to all details in the use of electric blasting caps (3) Adhering to safety precautions necessary to keep stray current at safe levels or excluded altogether.

The blaster in charge should consult with the appropriate detonator manufacturer for the testing and resultant actions to take at any time that stray current or other form of extraneous current is suspected in a blast area.

STATIC ELECTRICITY

Static electricity is electrical energy that is stored at rest on some person or object similar to the way that an electric charge is stored on a capacitor. Static charges are generated by the contact and separation of two dissimilar materials that include an approaching electrical storm, dust or snow driven by high winds and the rubbing together of different synthetic fabric clothing while a blaster is wearing rubber boots that would insulate him from the earth or ground.

Static electricity represents a very real potential hazard to electric detonators when three necessary conditions are satisfied in the proper sequence. The three conditions are generation, accumulation and static discharge. The generation condition is present when two dissimilar materials contact and separate. The static generation process is most efficient if the materials are rubbed together. The accumulation condition will exist when the static charge is stored or accumulates on some person or object that will serve as a capacitor. The static discharge condition will result when the charge is discharged into an object such as electric detonator legwires. This discharge can supply ample current to fire an electric detonator.

The static electricity problem can be eliminated if any one of the three necessary conditions can be eliminated. The generation process is inherent in nature because we don’t have any control over this condition. It is possible to prevent the accumulation of static charges and to minimized the risk of accidental detonation of electric detonators by a static discharge. Two actions can be taken by a blaster to help reduce the risk of static electricity: (1) ground all objects to earth of all which might store static charges (2) using electric detonators that are constructed to reduce the probability of accidental detonation by static discharge.

A very important point to always remember is that dangerous charges of static electricity can build up great distances from an electrical storm or storm center. Static charges can be stored on any insulated conductive body such as a person or truck and can discharge through the detonator legwires causing premature initiation. The shunt and insulation on the legwires of electric caps will not offer assured protection under these conditions because the voltages can be sufficient to break down the insulation. For this reason, blasters should never rely on the shunting of detonator legwires or blasting circuits for prevention of a premature blast. Also for this same reason, a blaster should always stop loading a shot and move to a safe distance if an electrical storm is in the area.

Instruments for detecting the proximity of an electrical storm are now in use at many mines. These instruments can provide warnings of hazardous atmospheric conditions, even when not in hearing distance or audible thunder or visible lighting. A less efficient way to detect static charges is static noises on an AM radio station tuned to a weak station. Explosive and detonator manufacturers can provide information on sources where more accurate detection instruments can be purchased.

A recognized warning system should be established to alert all operation personnel when potentially hazardous static or lightning conditions are detected near a blast area. This warning system would be evaluated and executed by the surface blaster and surface foreman, both of whom would have the authority and responsibility to stop loading of the blast and to evacuate all personnel to a safe area.

It must be remembered, though, that static electricity can be generated by means other than electrical storms. The movement of particles, especially under dry conditions, will generate static electricity. These particles may be freely suspended in the air such as dust or snow driven by high winds or imbedded in a moving insulator material.

Atmospheric static charges is a potential hazard in blasting subject to dust storms, snow storms and low humidity. Precautions to be taken in dust and snow storms include placing the electric detonators on the ground and slowly extend the legwires along the ground. The detonator legwires should never be thrown into the air when these conditions are present. Electric blasting should be suspended when severe dust or snow storms are present.

Atmospheric static charge potential is a particular hazard where electric blasting caps with long legwires are used. Long legwires intercept and store greater static charges than detonators with short legwires. Static atmospheric charges can also build up to a level that may initiate inelectric delay caps. This potential hazard is even more sever if the blaster is insulated from ground, such as wearing rubber boots or the blaster is wearing clothing on which electrostatic charges can be stored. The appropriate explosive-detonator manufacturer should be consulted for safe operating procedures before blasting in severe snow or dust storms.

Static charges can also be generated by mechanical means such as from equipment. All moving equipment in the blast area that can generate static electricity should be sent down while blasting circuits are being connected and until the blast has been fired.

Static electricity can also be generated when pneumatic systems are used to load ANFO. These electric currents are usually small but does constitute a hazard. A semiconductive loading system will help to bleed off the static charge as it is generated. The semiconductive hoses will also provide a path for the charges to drain to ground. Fully conductive hose should not be used because it can provide a low resistance path by which hazardous levels of stray current can be introduced into the blasting system. The appropriate manufacturer of pneumatic loading systems should be consulted for information and safety precautions when using this type equipment.

ELECTRICAL STORMS

Lightning and electrical storms represent the single greatest hazard to blasting because of the erratic nature and high energy. Lightning strikes are static energy discharges of gigantic proportions that can generate as much as 20,000 amps and a hot, high pressure gas column equivalent to the detonation of an explosive. These large amounts of electrical energy released by the powerful electric and magnetic fields associated with lightning represent a hazard to any explosive material. All or part of a blast probably will detonate if lightning strikes a blast area. Even distant lightning strikes can be hazardous to electric and nonelectric blasting systems because of the extremely high currents that are involved.

The blaster in charge must always remember that operation should be suspended and all personnel should be evacuated to a safe distance from the blast area whenever lightning storms are in the vicinity.

The danger from lightning is increased if there is a high voltage line, water line, fences, including electric fences, stream or other conductors to carry the current between the storm and the shot location.

Information data that has been collected on lightning related, premature detonations indicate that in most instances, the extraneous electricity was introduced into the blasting circuit by inductive coupling. Inductive coupling is the process by which electric energy is transferred from the primary to the secondary windings in a standard electrical transformer.

R F ENERGY

Electrical energy that travels through space in the form of radio or electromagnetic waves is radio frequency or R F energy. In tense, high radio frequency radiation can accidentally initiate electric blasting caps. Electric blasting circuit wires can act as does the receiving antenna on a radio or TV. It is possible for the circuit wiring to intercept sufficient energy to intercept sufficient energy to fire an electric detonator.

The probability of a premature detonation of an electric detonator is very remote because there are a number of conditions that must be satisfied. It is necessary that the blast site be relatively close to a high power transmitting antenna and that the blasting circuit of electric detonator legwires serve as an efficient receiving antenna. This valid conclusion is verified by the fact that but one or two accidents represent many the total unfavorable experience throughout the years during the use of many billions of electric detonators.

An investigation of any potentially hazardous source of R F energy near a blasting site should be conducted before any electric blasting caps are in the area. The intensity of R F current induced in a blast wiring circuit depends on radiated power, distance, frequency and wiring layout.

Current heats bridge wire independent of frequency. .05 amps will generate the same heat from a DC capacitor discharge blasting machine as from a radio or TV radio frequency.

The Institute of Makers of Explosives (IME) organization has conducted research, studied the problem and developed safety recommendations in the form of IME publication #20. This publication lists safe distances for various classes of transmitters.

R F energy sources that are emitted from several transmitters of different frequencies and power and thereby complicate even the safe distance tables in IME publication #20. The appropriate detonator manufacturer can provide assistance and guidance when a blaster feels that he may have problems with R F energy.

All available evidence indicates that normal radio frequency energy is not a hazard during the transportation of electric blasting caps in their original containers. The coiled or folded wires provide effective protection against induced current of R F energy. Metal truck bodies and freight car effectively prevent the penetration of radio frequency energy.

The following precautions should be observed if vehicles used to transport electric blasting caps are equipped with radio transmitters: (1) the caps should be carried in a closed metal box that complies with regulations for transportation of electric blasting caps (2) the transmitter should be turned off when the caps are either being put in or taken out of the box.

Blasters should always make certain that they have sufficient separation as outlined in IME publication #20 between their blasting operation and any R F transmitter and that all mobile transmitters are kept a safe distance from any blasting area.

The following general precautions will also increase safety and will also reduce hazards associated with conducting electric blasting operations near radio frequency energy sources: (1) make certain that there are no radio frequency transmitting antennas located closer to your blasting site than recommended in the IME publication #20. Be on the lookout for the installation of any new antennas and check any new installation before thy go into service to insure that they will not pose a hazard to your blasting operation. (2) keep mobile transmitters in the “off” position near blasting areas and place adequate signs to remind mobile transmitter operators. (3) determine if any directional radar antenna, which projects powerful beams over long distances, operate near the blast site and if so determine if electric blasting can be conducted safely.

HIGH VOLTAGE POWER LINES

Several potential hazards have to be associated with electric blasting near high voltage lines. Four factors should be considered when evaluating the effects a power line may have on an electric blasting circuit.

The first factor is that mining personnel may be electrocuted when a detonator legwire or firing line is thrown over the line power line by the blast. Special safety precautions must be taken to insure that these wires and lines do not contact power lines. The actual shot area should never be located closer to a power line than a distance equal to the length of the firing line plus the length of both legwires. Never extend firing lines under power lines. Also, the length of both legwires must be considered because the two single legwires may part and form one, long, single wire conductor. Anchoring legwires and blast wiring with a large rock is strongly recommended to help prevent this hazard. A blaster in charge must always remember that if a detonator legwire or any type of blast circuit wiring is thrown over a power line, the blasting crew must never attempt removal of the wire. The local power company should be summoned and requested to perform this task.

The second factor is that checks for stray current should be conducted prior to performing electric blasting operations near high voltage lines. By design, current flow through the neutral wire of three and four wire systems is low for balanced three phase systems. Some unbalance through, can result in possible stray current. The neutral wires are usually grounded at every tower or pole and some stray current may leak out into the earth along the right-of-way. Great care and extreme caution must be exercised when conducting the stray current tests to avoid direct contact of the test equipment with the high voltage line. It is advisable to consult with the power company when the tests are conducted to determine if measured voltages and currents may increase to a hazardous level when peak power levels are transmitted. This type test should not be conducted during a lightning storm because an extremely high current could be present.

The third factor is that overhead power lines can induce current in blasting circuits. AC electro-magnetic fields can induce current flow in nearby conductors. Electromagnetic fields exist in the vicinity of power lines, transformers, switches, ground returns, etc. and can induce a current directly into an electric blasting circuit. Induced voltages need a well defined closed circuit in order to establish a current flow. This type circuit can be formed by a series of electric detonators and its connecting lines. Series circuits hooked to connecting lines and or buswires could also form a close circuit or loop that is capable of intercepting induced electromagnetic field. The area enclosed by the loop of detonator legwires and circuit wiring should be minimized as much as possible to help reduce the intensity of induced current. The appropriate power company should be contacted and consulted in determining any induced current hazard near a blast site. The measurements should be made during peak load periods of the line.

A point that a blaster should always remember is that magnetic field lines form concentric circles around the high voltage line. Maximum pickup of the induced current results if the high voltage line and the circuitry or test loop lie in one plane. To help minimize induced currents, the firing line should be perpendicular to, rather than parallel with a power line.

The fourth factor is that lightning strikes that are a significant distance from a blast site could create a hazard. The high voltage ground wire will serve to intercept lightning strikes and assist in dissipating the surge current to earth. This surge “bleed off” of current should occur a short distance from where the strike occurs. It must also be recognized, though, that this surge current from a lightning strike could be carried a great distance.

UNIT VIII

BLASTING SAFETY

BLASTING SAFETY

PREVENTION OF MISFIRES

A misfire is defined as the failure of an explosive charge to detonate at the proper time. The soundest advice that can be given regarding misfires is to take every precaution to prevent their occurrence. A complete or partial misfire and any undetonated explosive material that remain after a blast is fired, does indeed represent a very hazardous situation until the unfired explosive material has been disposed of properly. Explosive misfire disposal requires sound judgment and a very thorough understanding of explosives by the blaster in charge. Most misfires occur because of improper techniques by the blaster, changes in the geological structure from the expected norm and detonators that are not wired into the circuit.

The best way to prevent a misfire is to become thoroughly familiar with the most common causes and always follow good, sound blasting practices. Twelve of the most common causes are discussed below with the corrective action for each: (1) poor wire connections – always clean corrosion, dirt and insulation off the wire ends before making connects. Always make clean, strong and secure electrical wiring connections. (2) bare splices on the ground, lying in water or wet areas – always keep bare splices off the ground and out of water or wet areas (3) improper detonator circuit – never use more detonators than there are recommended in a single series (4) improperly balanced detonator circuit – the resistances of the individual series should be balanced to within plus or minus 2 ohms and with a maximum of 100 ohms in each series (5) current leakage – check for current leakage and reduce the number of detonators per series if leakage is suspected to be a problem. Take safety precautions necessary to prevent stripping or abrading the protective insulation from the detonator legwires in boreholes. (6) mixing detonators from different manufacturers in the same blast – absolutely never mix detonators from different manufacturers in the same blasting circuit. (7) detonators not wired into the circuit – visually inspect the complete blast circuit by walking the shot area to insure that all detonators are connected into the circuit. (8) defective or inadequate firing line – the firing line must always have good insulation. Splices on firing lines should be staggered and well insulated with electrical tape. The size or gauge of the firing line should always be large enough to allow the power source being used to deliver adequate current to fire the detonator circuit. (9) inadequate power supply from the blasting machine – the blaster must always make sure that the blasting machine can deliver sufficient current to fire the blast circuit. (10) improperly made primers – primers should always be made up according to manufacturer specifications and instructions. (11) using nonwater resistant explosives in wet rock – only manufacturer approved wet-hole bags or borehole liners should be used for wet boreholes. (12) improper loading practices – priming and the loading of explosive should be managed according to manufacturer instructions.

If a blaster follows the proper methods of preparing primers, priming, loading, stemming, checking the blast circuit, and firing the blast, then the likelihood of a misfire is extremely small. Because every misfire is a potentially, hazardous situation, the safest way to handle a misfire is to prevent it. However, if a misfire does occur, then a blaster must know how to handle it safely. If a misfire does occur, always trace the cause and take corrective action to prevent future misfires.

Occasionally, the primer will detonate but will not initiate a portion of the charge in the borehole. This partial failure should be handled in the same manner as failure of the entire charge. Partial failures are usually caused by: (1) cutoff holes (2) improper or inadequate priming (3) deteriorated explosives (4) improper loading or drill cuttings between cartridges, if used. Borehole cutoffs can be minimized by properly priming the explosives at the bottom of the borehole, by properly delaying the blast and by designing the blast with due consideration to burdens, spacing, and visible seams or partings.

HANDLING OF MISFIRES

Every misfire warrants the title as a separate and distinct, potentially hazardous situation. Always remember that the safest and surest way to handle a misfire is to prevent it.

There are so many different types of blasting and blasting material that it is impossible to give blanket instructions for handling misfires. A blaster must always keep in mind that all work near or on a misfired blast site is a most hazardous operation.

It is most important that any investigation into the cause of misfires be conducted fairly, with an open mind. All misfires must be properly evaluated, analyzed and appropriate corrective action taken. Any preconceived idea of the cause may mask the true cause and prevent the establishment of thorough and methodical procedures necessary to handle this particular misfire and also to assist in preventing all future misfires. All information regarding a misfire must be analyzed completely and a plan of action outlined to safely handle, neutralize and dispose of explosives involved.

If a misfire does occur, these general safety precautions and steps could be taken in conjunction with consultation with explosive manufacturer assistance:

(1) Never allow any unnecessary personnel to return to the blast area. Explosive manufacturers recommend at least a 15-minute to 1-hour waiting period before any person returns to the blast area;

(2) The firing line should be disconnected from the blasting machine and be absolutely sure to shunt the ends of the firing line. Do not sound the “all clear” signal and be absolutely certain that all guards remain at their positions;

(3) Do not start any work in the area of misfires except that undertaken to remove the misfire hazard;

(4) After a sufficient waiting period, the blast area should be inspected by the blaster in charge. The investigation and correction of misfires should be made only with experienced personnel who should work in a methodical manner and without interference or confusion. Another individual, knowledgeable in misfire disposal should act as a safety back-up for the blaster-in-charge and remain out of the blast area but observe the situation from a safe distance;

(5) Carefully examine the applicable, misfired holes and or entire shot area to determine how many holes and how much explosives have misfired. All observable initiation system components must be identified and recorded. All unfired detonators or explosive materials should be treated as if they are "live." The condition and amount of rock surrounding the misfired holes or blast area should be determined. All undetonated explosives lying in the shot area should be picked up and stored awaiting appropriate disposal. An extreme caution is that misfired explosives must never be attempted to be re-used. The appropriate explosive manufacturer should be consulted for misfire explosive material disposal;

(6) The safest and surest way of handling any type of misfire is to be able to reconnect all the unfired charges and fire them successfully, if there is a sufficient rock burden around the boreholes to prevent fly rock hazards. This procedure is not always possible or practical because the misfired charges may have been cut off by rock movement and may be located in areas that are inaccessible to the blaster. The overburden rock may have been torn away by the charges with very little burden or burden that may have been shattered or displaced. The firing of this type misfired charges may result in uncontrolled and excessive flyrock. Attempts to confine misfired charge with mats, broken muck or screenings require extreme caution and should be attempted only after the situation has been thoroughly evaluated. A blaster must assume the worst case of consequences that can happen and take appropriate safety precautions if misfired charges are fired under these circumstances. The blast area must be totally isolated and the guards may have to moved to a greater distance in order to provide a greater zone of safety. The re-firing must be done from a remote, safe location. All personnel in adjoining work areas, yards, shops, etc. should be required to retreat to a safe place before the blast is fired;

(7) Be absolutely certain that the firing line is disconnected from the blasting machine or power source prior to entering the blast area. If the electric detonator legwires are accessible, test the cap or cap circuit with a blasting galvanometer or blasting multimeter. Absolutely, never use an electrician's volt-ohm meter when testing this or any other blasting circuit. If the detonator and or blast wiring shows a circuit and if sufficient burden is present for firing, then connect the circuit and attempt to fire in the usual manner. Electric blasting caps will detonate if the misfire was caused by a faulty connection or insufficient power. Absolutely, never pull on the wires of electric blasting caps because vigorous pulling on the legwires from a live cap could, cause a detonation;

(8) If the electric blasting cap fails again, if the cap legwires cannot be reached or if nonelectric initiators are being used, the borehole may be detonated with a fresh primer. If the stemming must be removed, great care and extreme safety precautions must be taken to prevent accidents. The best method is to remove the stemming with a water jet or air jet through a stiff rubber or plastic hose. The hose should be equipped with a valve to regulate the flow of water or air jets. Iron pipe or even a metal pipe tipped with rubber should never be used. Absolutely, it is not safe to use a metal tool, spoon, or auger for digging out the stemming;

(9) Insert a new primer and attempt to fire the charge with a new primer if it is not possible to remove the explosives after all the stemming has been removed;

(10) Do not return to the blast area for at least one hour after washing the stemming out and re-attempting to fire with a new primer. While removing the stemming, the original explosive charge may have been saturated with water to the extent that it will not detonate even from the impact of the new primer. However, the new primer may generate sufficient heat to start the, original misfire charge to start burning. This will result in a dangerous "hang-fire." Always remember, that the sound of the reprimed charge firing is not a dependable indication that it is safe to return to the blast area. Always allow at least one hour for "burning explosives" or "hang-fire" to detonate after this attempt to re-prime and re-fire the misfire;

(11) The least dangerous method to remove explosives from a borehole is with a water jet if repriming and refiring the misfire cannot be accomplished. This approach is to try to remove and or neutralize as much of the explosive charge as possible. In small diameter holes, it may be possible to wash out the stemming to permit the removal of these cartridges with a nonsparking retrieving tool. When large diameter holes have been loaded with bulk blasting agents, water can sometimes be used to wash out the charge. Water will neutralize ANFO and other similar type materials that have little or no water resistance. A blaster must remember though misfired charge requires a very thorough analysis, evaluation and judgment of the blaster in charge with consultation with the explosives manufacturer;

(12) It may be necessary to consider drilling, loading and firing of the boreholes adjacent to the misfired holes if it is impossible to re-initiate, retrieve or neutralize misfired holes. This action should be considered only as a last resort after all other courses of action have failed and then only after consulting the manufacturer of the explosive materials and initiation products for information, assistance and recommendations. The drilling, loading and firing of boreholes near holes containing misfired explosives is an extremely hazardous task that must only be undertaken by experienced, competent personnel utilizing extreme caution and care. Explosive accidents have occurred when drill steel strikes explosive material, especially dynamite products. When drilling boreholes adjacent to misfired holes, the hole location must be exact and the drilling operation should be monitored constantly by the blaster in the charge. Every precaution must be taken to insure that the drill bit will not intersect any explosive charge a thorough inspection should be made of the muck pile for displaced and unfired explosive materials after adjacent holes to misfires have been fired. The muck pile must be inspected continuously by experienced personnel to make sure that misfired explosive materials are detected and removed for disposal. An unresolved misfire indicates that the hazard remains and an extreme danger is present to personnel and equipment. Areas containing unresolved misfire charges may have to be abandoned and access restricted.

It must be emphasized that misfires, disposal of misfires or the working of personnel and equipment in an area where misfires are present is extremely hazardous. Only competent, experienced personnel should be entrusted to handle misfires under the supervision of the blaster in charge and surface foreman. In situations where there is any doubt or question regarding the properties of explosive materials, initiating devices or detonators that were used in a misfired blast, the manufacturer should be consulted for information, assistance and recommendations.

UNDER NO CIRCUMSTANCES SHOULD MISFIRED EXPLOSIVES BE REUSED

Burning or delayed initiation of a shot – complete or partial misfires may cause all or part of the charge to burn. This burning or "hang fire" may eventually result in an explosion. If the detonation of a column of explosives is interrupted or separated the charge may be set on fire. Burning explosives or "hang fire" can be caused by the "arcing" of delay detonators. Arcing can be eliminated to 25 milliseconds or less in each series. A hang fire can occur whether the boreholes are fired electrically or nonelectrically. If a burning charge is seen or suspected, then the location should not be approached for at least one hour after the apparent burning has stopped. The fumes from burning explosives are very toxic and must be avoided.

The main thing to remember about misfires is that they present a most dangerous and hazardous situation, and the safest way to handle a misfire is to prevent it.

BLAST AREA AND PUBLIC PERSONAL SAFETY

The prevention of explosive accidents depends on careful planning and faithful observance of proper blasting practices. The slightest abuse or misdirection of explosives may either kill or cause serious injury to yourself and others.

Very few blasting accidents are caused by lack of knowledge or experience. Blasting accidents are more frequently the result of a mental attitude that does not put safety before every other consideration. Rules, regulations and the most safety-alert foreman cannot prevent accidents. Only the proper attitude toward safety by the blaster and entire blasting crew will prevent explosive accidents. Safety is the individual responsibility of every person for his personal safety and the safety of his associates.

Two general statements should be acknowledged and understood about the safety and use of explosives:

(1) A blaster's most important responsibility is safety;

(2) The safety of every blasting operation depends on it's people.

The prevention of explosive accidents depend, to a large extent, on two factors: (1) the knowledge and experience of persons responsible for the use of explosives and (2) well defined safety precautions to guide the blasters and the blasting crew in the safe conduct of blasting operations. The prevention of explosive accidents depends on careful planning and faithful observance of proper blasting practices. The safety of every blasting operation is also dependent upon the attitude, knowledge, training and experience of the blaster and all miners who handle explosives.

Explosives by themselves do not cause accidents. Accidents are caused by the careless or thoughtless acts of people. The most important ingredients in a safety program are the quality of the people and the quality of their training.

The following guidelines should be followed in the selection of a blasting crew: (1) type of personnel (2) training of personnel (3) safety rules and regulations awareness (4) size of the blasting crew. Each of these guidelines will be covered in detail.

Type of personnel – All personnel designated to handle explosive materials should have intelligence, common sense and trained in the use of explosives. All personnel who handle explosives must know what is and is not safe. Blasters are trained to handle explosives and use their skill with discretion and safe judgment. Some personnel will never have the proper attitude to become safe handlers of explosive products no matter how much they are trained or how well they learn the technical aspects of blasting. Mining personnel who, through ignorance, carelessness or follow unsafe practices constitute the greatest problem to blasting safety. If a person is careless, reckless or unwilling to follow safe blasting procedures, then this type person should be removed from all contact with explosives.

Training of personnel – A new person should be schooled in blasting safety, government regulations, and the IME "Do's and Don'ts" before they handle explosives. All on-the-job training should be supervised by a careful, experienced blaster until inexperienced personnel demonstrate that they are capable of proceeding without close supervision. Good blasting safety programs take time, effort and careful planning if they are to achieve the ultimate goal of zero explosive accidents.

The following elements should be considered in planning and training for a blasting program:

(1) Repetition – Safety is a habit that can only be developed by repetition. It is unrealistic to expect every action of a person who performs during the working day to be a well, thought out, conscious act. Daily habits will help protect us from injury during these brief lapses. Good habits are developed only by constant, repeated training in performing a task in the correct manner until we instinctively perform acts in a safe manner;

(2) Personal Contact – The mine operator, surface foreman and surface blaster can only provide guidelines and direction to a safety program. The major responsibility for the success of a blasting program depends on the attitude and actions of the surface foreman and blaster who are in constant contact with the blasting crew. This direct contact with the blasting crew must be directed toward preventative action because corrective action is always the result of an accident or near miss;

(3) Safety Meetings – A safety meeting is an instrument used to convey knowledge and expertise to mining personnel. Accidents and mistakes by others can be discussed to educate and train other mining personnel. The mine operator, surface foreman and blaster in charge must actively promote safety with sincerity or else the program cannot succeed;

(4) Feedback – The vital importance of all safety meetings is the respect and response from the mining personnel. Safety meetings will present ideas and concepts that can provide a vital training tool if personnel are encouraged to participated and ask questions. Personnel attending safety meetings should feel relaxed and encourage to ask questions;

(5) Advertising – Safety must be promoted on a daily basis by observing and training personnel, safety meetings and plan information exchanges on blasting safety. The blaster and supervisory personnel must adopt and endorse good, safe blasting habits.

Safety Rules and Regulations Awareness – Mining Laws and safety rules-regulations must be explained to all personnel regarding the reasons why each exists. Both must be enforced without exceptions. Disciplinary action must be taken on a fair and equal basis but by the same token outstanding display and performance of safety practices must be recognized and rewarded in a manner that will display the emphasis and importance attached to safety.

Size of the blasting crew – A blasting crew should be as small as possible that is compatible with the size and conditions of the job. Casual labor should be used only when performed under the direct and constant supervision of the blaster in charge. Explosives should only be handled by well-trained and preferably experienced mining personnel. The keys to storage magazines should be under the responsibility of the surface foreman and blaster or other person appointed by the blaster in charge to distribute explosive materials. Complete and accurate records of inventory must be maintained on a daily basis. All transportation of explosive materials must be in a safe and properly designed vehicle. The total responsibility for “tying in” the blast, testing the blast circuitry and firing on a predetermined signal must be with the blaster in charge. The responsibility of clearing the blast area is usually closely coordinated by the surface foreman and the blaster in charge.

Flyrock is the most hazardous effect of blasting. It is a leading cause of onsite fatalities, offsite accidents and equipment damage from blasting. Occasionally, flyrock will leave the mine site and cause serious injury and damage to persons and property beyond the mine site. Flyrock distances can range from zero for a well-confined blast to a mile for poorly confined blasts. Flyrock is defined as an undesirable throw of material.

Flyrock is most often caused by an improperly designed or improperly loaded blast. Too narrow of a burden gives a powder factor that is too high for the material being blasted. The excess explosive energy results in long flyrock distances. On the other hand, an excessively large burden may cause violence in the collar area, especially when an inadequate or ineffective type of stemming is used.

To prevent or correct flyrock problems, the blaster should make sure that the burden is proper and that enough collar distance is used. One fourth inch crushed stone makes better stemming than drill cuttings, particularly poop practice where flyrock is a problem. In multiple row blasts, longer delays between later rows may help to reduce flyrock although precautions should be taken against cutoffs when using delays of this length.

Zones of weakness and voids are common causes of flyrock. These potential problems can sometimes be foreseen through consultation with the drill operator and through past experience in the area being blasted. An abnormal lack of resistance to drill penetration usually indicates a mud seam, a zone of incompetent rock or even a void. The driller should always note the location, depth and severity of zones of weakness in the drill log. Any explosive loaded in this zone will follow the line of least resistance and "blow out" causing flyrock. Placing a few feet of stemming rather than explosive, in this area will reduce the likelihood of flyrock. Void zones such as mine openings or solution cavities cause violent explosion when packed with explosives. It is always a good idea to measure the buildup of the explosive column as the loading proceeds. If buildup is abnormally slow, the zone should be stemmed and the powder column continued above it. Measuring the column buildup will also assure that adequate room is left for stemming above the charge.

Despite careful planning and good blast design, flyrock may occur and must always be protected against. Some margin of error must always be maintained. Abnormally long flyrock distances should be measured and recorded for future reference. The size of the guarded perimeter should take these cases into account. An adequate number of guards must be posted at safe distances. All personnel within this perimeter must have safe cover and must be adequately warned. Remember that warning signs, prearranged blasting times and blasting signals are not absolute guarantees against the hazards of flyrock. It is good if the blaster in charge has a commanding view of the blast area so he can abort the shot at the last minute if necessary.

The Virginia Surface Mining Regulations prohibits throwing flyrock more than one-half the distance to the nearest dwelling and beyond the property line owned or leased by the mine operator.

The surface foreman and blaster in charge should be thoroughly familiar with the preblasting survey, blasting schedule and the blasting sign-warnings-access routes as required by the Division of Mined Land Reclamation regulations 4 VAC 25-130-816.62, 4 VAC 25-130-816.04 and 4 VAC 25-130-816.66 respectively.

The following are requirements of the Division of Mined Land Reclamation regulation 4 VAC 25-130-816.62 pertaining to a preblasting survey:

(a) At least 30 days before initiation of blasting, the permittee shall notify, in writing, all residents or owners of dwellings or other structures located within ½ mile of the permit area about how to request a preblasting survey.

(b) A resident or owner of a dwelling or structure within ½ mile of any part of the permit area may request a preblasting survey. This request shall be made, in writing, directly to the permittee or to the Division, who shall promptly notify the permittee. The permittee shall promptly prepare a written report of the survey. An updated survey of any additions, modifications, or renovations shall be performed by the permittee if requested by the resident or owner. The request for an updated survey shall be in writing and describe the additions, modifications, or renovations which are to be surveyed.

(c) The permittee shall determine the condition of the dwelling or structure and shall document any preblasting damage and other physical factors that could reasonably be affected by the blasting. Structures such as pipelines, cables, transmission lines, cisterns, wells, and other water systems warrant special attention; however, the assessment of these structures may be limited to surface conditions and other readily available data.

(d) The written report of the survey shall be signed by the person who conducted the survey. Copies of the report shall be promptly provided to the Division and to the person requesting the survey. If the person requesting the survey disagrees with the contents/or recommendations contained therein, he may submit to both the permittee and the Division a detailed description of the specific area of disagreement.

(e) Any surveys requested more than 10 days before the planned initiation of blasting shall be completed by the permitted before the initiation of blasting. Any surveys requested after permit approval but less than 10 days before the planned initiation of blasting shall be completed by the permittee within 30 days of the request, except that reasonable time extensions be approved by the Division.

The following are requirements of the Division of Mined Land Reclamation regulations 4 VAC 25-130-816.64, pertaining to the blasting schedule:

(a) General Requirements

- (1) The permittee shall conduct blasting operations at times approved by the Division and announced in the blasting schedule. The Division may limit the area covered, timing, and sequence of blasting as listed in the schedule, if such limitations are necessary and reasonable in order to protect the public health and safety or welfare.
- (2) All blasting shall be conducted during daylight hours. The Division may specify more restrictive time periods for blasting.
- (3) Unscheduled blasts may be conducted only where public or permittee health and safety so require and for emergency blasting actions. When a permittee conducts an unscheduled blast, the permittee, using audible signs, shall notify residents within ½ mile of the blasting site and document the reason for the unscheduled blast in accordance with 480-03-19.

(b) Blasting Schedule Publication and Distribution

- (1) The permittee shall publish the blasting schedule in a newspaper of general circulation in the locality of the blasting site at least 10 days, but not more than 30 days, before beginning a blasting program.
- (2) The permittee shall distribute copies of the schedule to local governments and public utilities and to each local residence within ½ mile of the proposed blasting site described in the schedule.
- (3) The permittee shall republish and redistribute the schedule at least every 12 months and revise and republish the schedule at least 10 days, but not more than 30 days, before blasting whenever the area covered by the schedule changes or actual time periods for blasting significantly differ from the prior announcement.

(c) Blasting Schedule Contents
   (1) Name, address, and telephone number of the permittee;
   (2) Identification of the specific area in which blasting will take place;
   (3) Dates and time periods when explosives are to be detonated.
   (4) Methods to be used to control access to the blasting area; and
   (5) Type and patterns of audible warnings and all-clear signals to be used before and after blasting.

The following are requirements of the Division of Mined Land Reclamation regulation 4 VAC 25-130-816.66 pertaining to blasting signs, warnings and access control:

(a) Blasting Signs. Blasting signs shall meet the specifications of 4 VAC 25-130-816.11.
(b) Warnings. Warnings and all-clear signals of different character or pattern that are audible within a range of ½ mile from the point of the blast shall be given. Each person within the permit area and each person who resides or regularly works within ½ mile of the permit area shall be notified of the meaning of the signals in the blasting schedule.
(c) Access control. Access within the blasting area shall be controlled to prevent presence of livestock or unauthorized controlled to prevent presence of livestock or unauthorized persons during blasting and until an authorized representative of persons during blasting and until an authorized representative of the permittee has been reasonably determined that the permittee has been reasonably determined that
   (1) No unusual hazards, such as imminent slides or undetonated charges, exist; and charges,
   (2) Access to and travel within the blasting area can be safely resumed.

BLAST AREA RETURN

The surface foreman and blaster in charge must make certain that the previous shot did not produce any new or unforeseen hazards after every blast. Before returning equipment and personnel into an area recently blasted, responsible personnel in charge must: (1) wait until the postblast fume and smoke level is safe (2) inspect the blast results for undetonated explosives, especially in the broken rock muck pile if any boreholes have misfired (3) recognize and correct hazardous wall conditions.

Blast sites should never be re-entered after a blast until the concentration of fumes, smoke and dust have been reduced to safe limits. Smoke and dust can obscure the blaster's vision to the extent that dangerous wall and slide hazards cannot be recognized. Mining personnel who rush back into this low visibility area may injure themselves by falling over broken material or expose themselves unnecessarily to possible burning explosives that could detonate at any time. Noxious gases in sufficient concentrations may be present that would injure personnel who return to the blast area too soon. Even though postblast products generally dissipate rapidly, they still pose a hazard. Rushing to see the results of any blast may not only be unpleasant but hazardous and possibly could be fatal. Fumes are increased by any one or more of the following circumstances: (1) the use of products which provide inadequate water resistance (2) insufficient confinement (3) the use of damaged, deteriorated or inadequately primed explosives.

The blaster in charge and surface foreman should inspect the postblast area for all dangerous conditions that may pose a hazard to mining personnel. If explosives are suspected to burning in a blast hole, a 1 hour minimum waiting period must be observed. If dangerous conditions are encountered, the blast area should be dangered off until the dangers are eliminated. The complete blast area should be checked for misfires. Loose explosives or detonating cord in the muck pile often indicate a misfire. Detonator legwires, detonating cord or tubes extending from a borehole may indicate a misfire. Another indication of a possible misfire is an area of the blast that has not broken or pulled properly or an unusual shape of the muck pile. Other mining personnel and equipment must not be permitted in a postblast area until the blaster and surface foreman are certain that no hazards exist.

BLAST AREA PREPARATION

The preparation of a blast area begins with the drilling of boreholes. Before drilling begins, though, the blast area should be thoroughly inspected to make absolutely sure that all the explosives loaded in the previous blast were successfully detonated. Drilling into explosives that remain after the previous blast is one of the most frequent causes of accidents. The surface foreman, blaster in charge and drilling personnel should inspect and make sure the drill area is safe to work.

Some general indications of a previous blast misfire or cutoff is: (1) poor fragmentation and movement in certain areas of the shot (2) explosives on or in the muck pile (3) excessively hard digging, particularly at the toe.

If undetonated charges are found, they should be properly handled and stored awaiting for proper disposal by the appropriate explosive manufacturer.

When drilling has been completed and before moving the drill, each borehole should be checked for obstruction, water, etc. Any necessary redrilling can be done before any explosive material is brought in the area. Also, upon completion of drilling and rechecking all boreholes, the boreholes should be clearly marked with readily identifiable markers so that all boreholes are visible. In most situations holes that are too deep should be partially backfilled. Short holes and obstructed holes will require cleaning or redrilling.

Before the first borehole is loaded when the explosives arrive and after the drill has been removed, a final check of borehole condition should be performed.

Several precautions should be taken before the loading operations begin: (1) all unnecessary personnel must be removed from this area because all persons that are not essential to the loading operation should leave. Observers should be under the control of the blaster in charge who will make sure they do not create a hazard; (3) all electrical power that might create a hazard should be disconnected. If extraneous electricity is suspected, appropriate checks should be made with a blasters' multimeter. A nonelectric initiation system may have to be used if extraneous electrical hazards cannot be eliminated; (4) two-way radios in the vicinity should be turned off and electric blasting should only be conducted a safe distance from transmitter stations according to the American Table of Distances.

Before loading begins, equipment should be moved and not permitted to operate in the area where explosives are being loaded.

Use the right explosive for the job. Primers and explosive selection must fit the situation. For example, explosives with inadequate water resistance should not be used in wet boreholes.

Take extreme care when loading hot boreholes. Some explosives may ignite and detonate upon contact with such extreme temperatures. The safest procedure is not to load any borehole until one hour after it has been drilled. No explosives should be loaded if the temperature inside a borehole exceeds 150 degrees F. Explosive manufacturer assistance should be requested on questions involving loading hot boreholes.

The cardinal rule of primer makeup is that primers should only be made up as close as possible to the blast site. The detonators and primers should be brought to the blast site as separate components. The primers should be made up according to manufacturer guidelines.

If an electrical storm approaches at any time when explosives are present, the area must be vacated. Weather reports, lightning detectors, or even AM radio receiver static may serve as a warning of an approaching electrical storm.

The column buildup should be checked frequently using a weighted tape. If the column buildup is less than anticipated, the result may be a cavity that will fill with explosives and blow out violently when detonated. If the column builds up more quickly than expected, frequent checking will prevent overloading. Excessive column buildup will result in inadequate stemming and excessive flyrock may result.

A general rule of thumb for the amount of stemming should be 14 to 28 times the borehole diameter.

Primer cartridges or primers should be lowered into the borehole to prevent damage to the primer, electric detonator legwires or detonating cord. Also "wet hole" bags of ANFO should never be dropped into a borehole. The wet hole cartridge provides water resistance and dropping may break the cartridge causing leakage and subsequently, desensitized ANFO.

The size of the crew used to hook up the shot should be kept to an absolute minimum with the blaster in charge in absolute control. The blaster in charge is in charge of the final wiring and circuit checks to assure that the blast is ready to fire.

More people are injured and killed during the blast firing operation than any other phase of blasting. This is usually due to inadequate guarding, improper signaling or other unsafe practice that allows a person to be too close to the blast site upon detonation. The surface foreman and blaster in charge must make absolutely sure that all mining personnel are removed to an area that is protective of potential fly rock.

The blaster in charge should allow time immediately before firing the shot to inspect the blast area for any last minute problems. The blaster in charge is always in direct control of the blasting machine.

The surface foreman and blaster in charge must make sure that sufficient guards are available to seal off the area and protect all persons from entering the blast area. The guards should proceed outward from the blast area, clearing all personnel from the area as they proceed. Any blast should not be fired until all persons are cleared from the blast area. When the guards have sealed off all possible entrances to the blast area, no one is allowed to pass unless authorized and coordinated by the surface foreman and blaster in charge.

A warning siren must be sounded before all blasts. All guards must remain at their positions until the all clear signal is sounded.

UNIT IX

BLAST INSTRUMENTS

BLAST INSTRUMENTS

BLASTING GALVANOMETER

First of all, electrical testing devices are invaluable in conducting blasting operations using an electrical initiation system. Only devices that have been specifically designed for blasting should be used to test and check blasting circuitry. These devices only produce small currents that will not cause electric blasting caps to detonate. Electrician's instruments, absolutely, must not be used to test any blasting circuitry or wiring. Electrician's instruments such as a volt-ohm meter can pass large enough currents through the blast wiring to detonate the shot. Blasting instruments that are maintained and used properly have a maximum output of less than one-tenth of the current necessary to fire an electric blasting less than one-tenth of the current necessary to fire an electric blasting detonator. The electrical devices that should be used for testing blasting circuitry are the blasting galvanometer, blasting ohmmeter and blasting multimeter.

The blaster's galvanometer is a test instrument used to measure resistance which is a property of all materials that affects the amount of current that can flow through it. The galvanometer is used to make continuity checks and resistance checks on a single electric detonator, a detonator circuit, a complete blasting circuit and a firing line. The galvanometer will provide a blaster with information necessary to determine if the detonator legwires are intact, to determine the continuity of circuits and to locate broken wires and or loose connections in a circuit. If you know the resistance of a blast circuit, then you can determine whether or not the electrical current supplied by your blasting machine will be sufficient to fire the-circuit. The galvanometer is also used to find broken wires, shorts and grounds.

To measure resistance with this instrument, place each of the two wires from the open end of the circuit on the two contact posts that extend out of the top of the galvanometer. The meter's top scale measures resistance in ohms and the larger numbers on the bottom scale are only reference points and do not relate to the actual number of ohms in the circuit.

Measuring resistance with a test instrument is the primary checking factor while testing a blast instrument. By knowing the manufacturer specified resistance, the measurement as observed on a galvanometer can be compared to the specified resistance for confirmation.

The galvanometer must always be zeroed before using. Zeroing a galvanometer is made by placing a piece of wire across the two terminals and observe the meter's face for a zero reading. If the needle has not moved to zero, then turn the adjusting screw on the back of the meter until you get a zero reading. If the needle does not move at all, the battery probably needs replacing. If the needle does not move at all, the battery probably needs replacing. If a new battery will not enable the needle to zero, then the galvanometer should be repaired by the appropriate manufacturer.

After testing any blasting circuitry that have shunts, the shunt should be re-made after the test has been completed.

The following are common test that are made on electric blasting circuitry: (1) test the detonator legwires for continuity and resistance prior to insertion into a borehole (2) test the detonator again after loading the explosive column but before stemming (3) test the detonator legwires again after stemming before proceeding to the next borehole (4) test the continuity and resistance of each series (5) test the circuit after the connecting line has been installed (6) test the firing line for continuity and resistance before hooking to the connecting line (7) testing the complete blast circuit after the firing line has been hooked to the connecting line.

The following are common things to look for in blasting circuitry: (1) if the resistance is much less than the computed resistance, then check each cap for shorted legwires and if in a series circuit, check to make sure all detonators are wired into the circuit; (2) if the resistance is much greater than you computed, check for a possible poor connection; (3) if you have a very high resistance or the needle on the meter does not move at all, you have a possible open circuit, a broken wire or a missed connection.

A blaster must always remember that the computed and or specified resistance of a detonator, a series circuit, or the complete blast circuit should be nearly the same as read on the galvanometer. A blast should never be attempted to be fired if the computed resistance does not equal to the measured resistance.

If you have erred in the design and or circuit resistance such that the total resistance is more than the capacity of the blasting machine, then you must either re-design and rewire the circuit or obtain a larger capacity blasting machine.

Some critical things must always be remembered about the batteries used in a galvanometer. First of all, only special silver chloride batteries or other galvanometer manufacturer recommended batteries must be used to power the instrument. Secondly, never use any other battery other than a silver chloride battery or galvanometer manufacturer recommended batteries and absolutely never change batteries in the vicinity of electric blasting caps. Thirdly, never allow a silver chloride or any other battery to come in direct contact with electric blasting caps.

The galvanometer has an adjustment screw on the back of the instrument that is used to zero the needle when a conductor is placed across the two terminals. The battery should be replaced when the galvanometer cannot be adjusted to a zero-ohm reading on the top scale. When the battery is bad, it must be replaced with the same type of silver chloride battery or other galvanometer manufacturer, recommended battery.

The blasting ohmmeter is so similar to the blasting galvanometer that it will be discussed now. The ohmmeter is used to measure the resistance of blasting circuitry and is similar in appearance to the galvanometer. The ohmmeter is zeroed and functions similar to a galvanometer. If the needle is weak and should be replaced. The ohmmeter, as with all blast measuring instruments, should not be used if it cannot be adjusted to zero. The ohmmeter battery should be replaced with the type and size as specified by the manufacturer. The ohmmeter should be operated, maintained and used in accordance with manufacturer instructions.

BLASTING MULTIMETER

The blasters' multimeter is a versatile, multi-purpose test instrument that is specifically designed to measure resistance, voltage and current in electric blasting operations. This multimeter is powered by an appropriate manufacturer recommended battery.

A selector switch on the front of the meter case is turned to the desired position for measuring voltage, current or resistance. The two test leads plug into the case of the meter, usually on the front. Special current limiting circuitry in the meter insures that the test current introduced into the blast circuit does not exceed 25 milliamps. Each multimeter is provided with an instruction manual from the manufacturer that lists the meter specifications and procedures for performing tests.

The following is a list of general tests that can be performed with a blasting multimeter: (1) blasting machine output voltage (2) AC and DC power line voltage (3) detonator and blasting circuit resistance (4) "opens" or "shorts" in the firing line (5) current leakage (6) AC and DC stray current (7) static electrical hazards.

For detailed information on field use and operation, refer to the instruction manual.

CAPACITOR DISCHARGE BLAST MACHINE

The blasting equipment used to fire the blast is an important part of any blasting operation and must be of excellent quality. Blasting equipment must be maintained in top condition at all times. Never attempt to use a blasting machine that is not operating properly.

Capacitor discharge blast machines have a bank of capacitors that store a large quantity of electrical energy this is supplied by dry cell batteries. The capacitors are charged by pressing the "charge" button or switch. A blaster can discharge the stored energy in the capacitors into the blasting circuit by pushing the "firing" switch. Capacitor discharge (CD) blasting machines can fire many electric blasting caps in relation to their weight and size. CD machines are the most reliable means for firing electric detonators.

The firing circuit calculations for CD blasting machines are complex because the voltage and current change continuously as the blasting machine discharges. The ready-to-fire lights and or voltage meters indicate full voltage across the capacitors. However, this light or meter does not provide a capacitor check and therefore does not insure that the machine will deliver its rated energy output. Frequent testing by a qualified electronics shop is recommended to insure that the machine will deliver full-rated energy output.

Unless restricted by manufacturer instructions, general maintenance is restricted to changing batteries. Batteries must be changed in accordance with manufacturer instructions because the electrical discharge from blasting machines can be fatal. No repairs or alterations of any type should be attempted in the field.

The CD blasting machine is a highly efficient and dependable machine designed to produce optimum results under virtually all conditions. Most CD machines are provided with a signal light that glows when it is charged and ready to fire. The machine can be fired by pressing the fire switch or button while continuing to press down the charge switch or button. Most CD machines will not fire if the charge button is released and then pressing the fire switch. Manufacturers feel this is a safety device because the blast can be stopped at any time before the fire switch is depressed. Most CD machines will not fire a blast unless the “charge” and “fire” switches are operated together. These are only general operation guidelines and the blasting machine manufacturer representative should be consulted for operating and maintenance information.

The CD machine is rated according to its ability to set off a certain number of blasting caps. A blaster must never exceed the number recommended by the manufacturer or a misfire could occur.

The CD machine, when used properly, is the most dependable means of firing electric detonators. The initial current from a CD machine must be considerably in excess of the minimum DC firing current required for a circuit because of the rapid current dissipation. The total resistance of a blast circuit must be calculated and using Ohm’s Law, it can be computed if the blasting machine has sufficient energy to supply the required current to fire the blast. A blaster must never exceed the capability of their blasting machine when firing a blast.

The sequential timer is another CD blasting machine that is actually multiple machines in one unit. It functions in such a manner that it will energize multiple electric blasting cap circuits in a programmed time sequence. This timing system provides blasters with a greater number of delays than is available with the use of electric caps energized with a conventional blasting machine. The sequential timer is commonly used when blasting operations need to limit the amount of explosives – fired – per-delay period to help control noise and vibration effects. This will allow a blaster to increase the total size of the shot without increasing the noise or vibration effect. The combination of a sequential timer and delay detonators provide flexibility in shot design. Improved fragmentation and control of fly rock are generally obtained with properly designed sequential timer controlled blasts.

As with all blasting equipment, the manufacturer representative should be consulted for operation and maintenance information.

UNIT X

EXPLOSIVE SAFETY

EXPLOSIVE HANDLING SAFETY

EXPLOSIVE TRANSPORTATION SAFETY

State and Federal Regulations and the Bureau of Alcohol, Tobacco and Firearms Department govern the transportation, storage, handling, use and theft of explosive materials. These regulations are designed to minimize hazardous exposure of the public and mining personnel and insure that the explosives remain stable in class A condition. Even though regulations are intact, a blaster must also adhere to explosive materials manufacturer instructions.

The Department of Transportation (DOT) regulates the interstate commerce of explosive materials. The explosive manufacturer is responsible for explosives while on public highways and the mine operator assumes the responsibility when the explosives are delivered to the mine site. The Bureau of Alcohol, Tobacco and Firearms are empowered to investigate cases of theft of all explosive materials and should be notified in all cases of suspected theft.

The following are general guidelines, in addition to State and Federal Laws that should be adhered to while transporting explosives:

Vehicles: All explosives must be transported in a well maintained vehicle. It should have a nonsparking area or nonsparking floor to transport explosive materials. Explosives must never be loaded above the sides of the vehicle body. Each vehicle used for transporting explosives must have at least one fire extinguisher.

Vehicle Operation: A vehicle should be inspected prior to transporting explosives to insure its safety equipment is operating properly. This inspection should include: (1) vehicle body (2) brakes (3) steering (4) lights (5) horn (6) tires (7) windshield wipers (8) fuel tank and lines (9) mirrors (10) reflectors (11) explosive placards.

Smoking must not be permitted in or around a vehicle when loading, transporting or unloading explosive materials. A vehicle should always be refueled before transporting to avoid the risk of an additional hazard. If absolutely necessary to refuel while transporting explosives, the engine must be stopped and the ignition turned off. No spark-producing metal, tools, oils, matches, firearms, batteries, flammable substances, acid, oxidizing materials or corrosive compounds should be carried in the body of a vehicle while transporting explosive materials. Blasting detonators must be located in a separate compartment when transported in the same vehicle with other explosive material. Except in true emergencies should an explosives carrying vehicle park near a public dwelling, building or other place where people work or assemble, even though the vehicle will be constantly attended. The driver of an explosives vehicle must know the nature of the explosives and trained in the proper emergency procedures if a fire or other incident creates a hazardous situation.

Drivers: The driver of an explosives carrying vehicle must be physically fit, careful, capable and reliable. The driver must never be under the influence of intoxicants, narcotics or other drugs. A driver must obey all laws and regulations that govern transporting explosives materials which include items such as stopping at railroad crossings, stop signs, etc. The driver must insure that the vehicle is kept free of excessive oil and grease to help minimize the chance of fire.

EXPLOSIVE STORAGE SAFETY

The storage of explosive materials is under the jurisdiction of the Bureau of Alcohol, Tobacco and Firearms, Department of the Treasury, even though State and Federal government regulations do exist. The theft or suspected theft of all explosive materials must be reported to the ATF, State and Federal government and state and local police.

There are five types of explosive magazines as approved by the ATF, Type 1 through Type 5. Each type magazine has specific construction, restriction, limitations and storage requirements as required by the ATF.

There are three classifications or explosive materials, Class A, B, and C. Class A includes the explosive of maximum hazard such as dynamite, detonators, primers, detonating cord, cap-sensitive primers, etc. Class B includes the explosives that deflagrates such as fireworks and therefore will not be discussed. Class C includes the explosives of minimum hazard such as ANFO, non-cap sensitive slurries, etc.

A type 1 magazine is a permanent building for bullet sensitive materials that can mass detonate. Class A explosives are required to be stored in this type magazine. This magazine must be bullet proof, fire proof, theft proof and weather resistant. Detonators cannot be stored in this same type magazine with other high explosive such as dynamite, primers, etc.

A type 2 magazine is the same as type 1.

A type 3 is a portable magazine such as a day box that also must be bullet proof, theft proof, fire proof and weather resistance.

A type 4 is a permanent or portable magazine for storing explosives that are not bullet sensitive and will not mass detonate.

A type 5 is a permanent or portable magazine for storing explosives that are not bullet sensitive. A type 5 must be weather proof and theft resistant and includes a building, trailer, bin, etc. that is used to store blasting agents such as ANFO, slurry, etc.

On most surface operations, 2 or 3 type 1 and 1 or 2 type 5 magazines will be used to store explosive materials. Electric detonators will be stored in one type 1 magazine while another type 1 magazine will be used to store the primers because electric detonators cannot be stored with any other type of high explosive. Type 5 magazines such as ANFO storage bin or ANFO trailer will be used to store the blasting agents.

All explosive magazines should be remotely located with public safety, security and access considered. The American Table of Distance specifies minimal distances for various quantities of explosives between off-site inhabited buildings, highways and other magazines. Magazine sites should be as remote as possible in areas that provide good, natural barricading. The access to sites should be limited and secured against possible theft. Good roads designed to handle truck traffic should be accessible. The sites should be located such that explosive haulage roads are not congested.

Magazine constructions must be such that they are bullet, fire, theft and weather resistant. The bullet resistance applies only to explosives that can mass detonate such as Class A explosives.

Ventilation requirements depend on climatic conditions and State and Federal Regulations. Vents are usually in the lower sidewalls or ceiling. These vents should be screened to keep out varmits and shielded to provide weather and bullet resistance. Unless air circulates freely and adequately through a magazine, it could become hot and humid enough to deteriorate explosives, blasting agents, detonators, etc. Extreme temperature variations will accelerate this deterioration. Painting the magazine exterior with a reflective color (aluminum or white) helps reduce the possibility of such temperature variations.

Magazine interior must be a non-sparking material.

Permanent magazines shall have no openings except for a door and properly designed ventilation vent.

Every magazine should be inspected at regular intervals to determine if there have been any attempted theft or unauthorized entry. Any theft or attempted theft must be reported immediately to the ATF and to State and Federal authorities.

Magazine doors should be kept locked except when materials are being handled and during inspections. The keys should be carefully controlled and only competent, authorized personnel should have access to explosive magazines. Two locks are required on all type 1 magazines.

"Explosive Keep Out" warning signs must be posted near the magazines such located so that a bullet striking the sign would not strike the magazine.

Magazines should be used exclusively for storing explosive materials.

If an explosive burst, spills, etc. or is found deteriorated, the appropriate explosive manufacturer should be contacted for possible clean-up and or disposal.

When a new shipment is received, the stock should be arranged so that the older stock will be used first. Corresponding grades, sizes, etc. should be stored together and the cases arranged so that the grade and size markings are visible for easy counting, checking and inspection.

All explosives and detonators must be neatly stored in closed boxes which should be upright and stacked in a stable manner. Damaged or deteriorated explosives must be handled and moved with the assistance of the appropriate explosive manufacturer. Primers must never be made up or stored in a magazine with other explosives. Damaged or deteriorated explosives should be stored in a separate magazine while awaiting disposal by the appropriate explosive manufacturer.

Only explosive manufacturer recommended lights that are approved by State and Federal Authorities are allowed in or around magazines.

If the interior of a magazine is to be repaired or if the exterior is to be repaired in such a way that sparks or a fire could result, then all explosive materials must first be removed and safely stored for the duration of repairs.

These are only general requirements necessary for the safe storage of explosive materials. Other requirements are enforced by State, Federal and ATF Authorities.

EXPLOSIVE HANDLING SAFETY

The handling of explosives involves many different safety procedures, State Law and Federal Law.

The following is a list of safety principles that should be adhered to:

(1) Explosives should always be handled carefully, kept dry and protected from shock, friction, fire or sparks;

(2) Always load and unload explosives very carefully. Never throw explosives into or from a truck;

(3) Never allow smoking or unauthorized personnel in or around an explosive vehicle;

(4) Never permit metal, flammable or corrosive substances to contact explosive material;

(5) Never abandon any explosives in any location for any reason;

(6) Explosives and detonators should be kept apart until the very last moment before loading boreholes;

(7) Never make up primers near a magazine or other explosive materials;

(8) Wires of electric detonators should be kept from contacting stray current or other sources of electrical energy;

(9) All explosives and detonators that are not used by the end of the day should be returned to the proper storage magazine;

(10) Never handle or use an explosive unless completely familiar with the explosive and the correct, safe procedures for its use;

(11) Never use metal tools to open explosive containers;

(12) Never carry explosives in the pockets of your clothing or in any unauthorized container;

(13) Never use explosives that are damaged or deteriorated;

(14) Never strike, tamper, investigate or attempt to remove the contents of a detonator or attempt to pull the wires out of a detonator;

(15) Never attempt to use any explosive material that has been water – soaked even if apparently dried out. Consult the manufacturer for specific instructions when dealing with water soaked explosives;

(16) Never handle, use or be near explosives during the approach or during an electrical storm. All personnel should retreat to a safe location;

(17) Always make up primers in accordance with manufacturer instructions;

(18) Never force a detonator into a primer;

(19) Never attempt to force explosives into a borehole or through an obstruction in a borehole;

(20) Always avoid placing any unnecessary part of the body over or in front of a borehole when loading;

(21) Never deform, drop, tamp or abuse a primer and never drop any other cartridge on top of a primer;

(22) Never load explosives in a hot borehole because borehole temperatures in excess of 150 degrees F. are dangerous;

(23) Never stack surplus explosives near working areas during loading;

(24) Always handle detonating cord with the same respect and care given to all other explosive products;

(25) Never attach blasting caps or electric blasting caps to detonating cord until everything else is in readiness for a blast.

THE "DO'S AND DON'T'S" CONTAIN MANY MORE PROCEDURES TO FOLLOW FOR SAFE HANDLING OF EXPLOSIVES.

EXPLOSIVE DESTRUCTION

The Institute of Makers of Explosives (IKE) recommends that all explosive material destruction be referred to an explosive distributor whether or not they handle the explosive in question. The applicable explosive distributor should handle any unwanted explosives if available. If the applicable explosive distributor is not available, then the blaster in charge should contact the nearest explosive distributor for the destruction of all explosive materials.

A blaster must always remember that damaged or deteriorated explosives are more hazardous than explosives in good condition.

Dynamite that has deteriorated presents an extremely dangerous hazard because of the nitroglycerin content. A main point to always remember about dynamite: Dynamite that has leaked excessively, indicated by saturated material in the bottoms of boxes or stained boxes should never be touched until a representative of the manufacturer has been contacted and is present.

When properly stored and cared for, dynamite will remain in good condition for long periods of time. Otherwise, it will deteriorate. Even though it is not widely used, dynamite is used as primers at some surface though it is not widely used, dynamite is used as primers at some surface operations. Dynamite with obvious signs of deterioration such as hardness, discoloration, excessive softness or leaking stains should be referred to the manufacturer for disposal.

The appropriate explosive manufacturer should dispose of all unwanted, damaged, or deteriorated explosive materials.

EXPLOSIVE WET HOLES

Wet boreholes present a problem that must be properly managed in order to conduct a safe and successful blasting program. Explosive products penetrated by water will have their efficiency impaired first and upon prolonged exposure may be desensitized to the point where they will not detonate. Insufficient water resistance of an explosive will also increase the amount of poisonous fumes liberated upon detonation. All explosive materials that have been subjected to water should be referred to the applicable or nearest explosive distribution for disposal.

The water resistance of an explosive depends on the packaging, explosive inherent ability to withstand water, and whether the water flow is static or moving. Fast moving water affects explosives quicker than static water.

Explosives differ widely in their ability to resist the effect of water penetration. ANFO in bulk form does not have any water resistance. “Wet Hole” ANFO bags depend entirely on their packaging to resist water penetration. The packaging may be polyethylene – lined tubes or plastic bags. Both, though, will only provide minimal water resistance when loaded into water filled boreholes.

Wet-hole bags can easily become separated by floating in water or mud in the borehole. Frequent priming of every other bag can help overcome the substandard performance from this problem.

Watergels and dynamites do have some inherent ability to resist the effects of water. Despite this inherent resistance, some severe field conditions can desensitize these products. It is recommended that these products not be removed from the packaging and should never be cut into small sections. The packaging does improve the products water resistance.

In severe water conditions, a water resistant product should be loaded as packaged and shot as soon as possible. Blasters must know their water conditions and use products that will perform safely under these conditions.

ANFO, the most common blasting agent, functions best when loaded in completely dry boreholes. The borehole check prior to loading any explosive in the first borehole should reveal to the blaster whether or not water conditions are present.

A blaster in charge should always consult with the appropriate explosive manufacturer if there is any question regarding the water resistance of an explosive product or the proper procedure for loading wet boreholes.

ANFO "wet holes" bags contain a densified mix that enables the cartridge to sink in water. Wet hole bags should be lowered and never dropped into a borehole. Poor blast results usually result when ineffective measures or wet hole bags are ruptured. Wet hole bags, though, do have a disadvantage of borehole coupling and should only be used in wet holes.

In addition to wet hole bags, the other measure taken to combat water problems is by the use of a borehole liner.

UNIT XI

BLAST EFFECTS

BLAST EFFECTS

AIR BLAST

Explosive manufacturers, mine operators and government agencies have spent substantial amounts of time and effort in order to gain a better understanding of the relationships between blast variables and the blast effects of air blast and ground vibration. Much knowledge has already been gained and numerous studies have yielded guidelines for the case of delay blasting and modern monitoring techniques. These studies and guidelines, if used, will help reduce the likelihood of damage to domestic structures and hopefully reduce the number of public complaints.

Blasters can overcome the complaints about noise and vibration through careful blast design with effective use of delays, by careful monitoring of the blast effects and by meeting with neighbors to explain the care and safety precautions used to protect their property and safety. The communication exchange and keeping the public constantly informed is a big factor that will help to reduce the number of complaints. Blasters must continue to analyze blast design, monitor effectively and maintain accurate records in an effort to reduce persistent complaints. The records of blast design and blast effect are very important factors when government agencies investigate and discuss the problems of complaints.

The two most common complaint problems are air blast and ground vibration.

In order to help reduce and or avoid air blast complaints, a blaster must understand the relationship between an explosive blast, weather conditions and an air blast.

The air blast from an explosive detonation is a compressional wave in the air. It is cause either by the direct action of explosive products from an unconfined explosive in the air or by the indirect action of a confining material subjected to explosive loading. Noise is the portion of the spectrum that lies in the audible range from 20 to 20,000 hertz. The concussion of a blast results from the spectrum below 20 hertz.

The use of the scaled distance formula used to compute charge-weight per-delay permits the prediction of blast effects over a large range of charge weights and distances.

An accurate and complete measurement of air blast from explosive sources requires a sufficient band width to include all frequency components or ranges. The low frequencies can cause damage to structures but usually are perceived as noise that rattle windows, doors, etc.

When a large number of explosive charges are detonated with small time delays between them, the air blast pulses from the individual charges may superimpose in a given direction and produce a strong air blast.

Atmospheric conditions affect the intensity of noise from a blast at a variable distance. These conditions determine the speed of sound in air at various altitudes and directions. The speed of sound is determined primarily by two factors: (1) temperature and (2) wind speed. Normally the air temperature decreases as the altitude from the earth's surface increases. A temperature inversion exists if the air becomes warmer as the altitude increases.

If the weather conditions (temperature and wind velocity) are such that a greater sound velocity in any direction occurs above the earth's surface, a sound speed inversion exists and therefore bends the sound rays back toward the earth's surface.

When a temperature inversion exists, the temperature and sound velocity increases with altitude. The sound rays will bend back toward the earth's surface but will decrease more slowly with distance than with sound speed inversion.

Conversely, when the temperature decreases with altitude and sound speed, the sound rays are refracted away from the earth's surface. This condition is more stable and is the most frequent condition during the time of the most surface blasts. With this condition, the noise level decreases rapidly with distance.

The public relations problems involving air blast with the use of explosives have increased in the past years. The increased difficulty that blaster face with public relations is the result of urban expansion and the commencement of surface operations near densely populated areas. When blast effects intrude upon the public's comfort, strained relations usually arise between operators and surrounding communities.

An air blast, whether audible or inaudible can cause a structure to vibrate in much the same way as ground vibrations. Air blast is measured with an integral part of a blasting seismograph machine. Both amplitude and frequency are measured. The amplitude is measured in decibels or pounds per square inch and frequency is measured in hertz. Air blast from a typical surface blast has less potential than ground vibration to cause damage to structures. However, air blast is a frequent cause of complaints. When a person senses vibration from a blast or experiences house rattles, it is usually impossible to tell whether ground vibrations or air blast is being sensed. A thorough discussion of air blast is a vital part of any surface mine-public relations program.

Air blast is usually caused by one of three mechanisms. The first cause is energy released from unconfined explosives such as uncovered detonating cord trunklines or mudcapping used in secondary blasting. The second cause is the release of explosive energy from inadequately confined borehole charged resulting from inadequate stemming, inadequate burden or mud seams. The third cause is movement of the burden and the ground surface. Blasts are designed to displace the burden. When the free face moves out, it forms an air compression wave that results in air blast. For this reason, locations in front of the free face receive higher air blast levels than those behind the free face.

Because air blast is a major cause of blasting complaints, some operators choose to seismograph all surface blasts. Air blast, though, does result in a potential for structural damage. Air blast recordings provide good evidence in case of complaints or law suits. Air blast readings taken in conjunction with ground vibration readings are especially helpful in determining which of the two is the primary cause of complaints.

In the early morning, a temperature inversion may be present following clear nights with low wind speeds that prevent mixing of the atmosphere. The lack of cloud cover allows the temperature of the ground and air above it to drop rapidly creating the inversion. Blasting done in the early morning will result in loud noise levels. As mid-morning arrives, the sun's rays will cause the ground temperature to warm and rise and the increased ground temperature warms the air in contact with it. This process will continue throughout the day and the mid-morning. At this time, favorable conditions for blasting are present. Near and after sunset, the temperature of the earth's surface begins to cool and a low altitude inversion may exist.

The presence of cloud layers signifies the presence of a temperature inversion. The commonly accepted idea that noise is reflected from the bottom of clouds is mistaken. The clouds signify the presence of an inversion which refract the sound back toward the earth's surface.

Changes in sound velocity with altitude may also be caused by wind. Wind is highly directional. Normal wind increases with altitude and therefore causes an increase of sound speed with an increase of altitude. The wind direction results in an increase or decrease in noise levels in the down wind direction. The effect of wind on noise levels is generally the greatest in the winter months because of the higher wind speed that is present during this time of year. In the warmer months, wind speeds are normally lower and help prevent the formation of temperature inversions.

The following are favorable atmospheric conditions for blasting:

Clear to partly cloudy skies, light winds and a steady increasing air temperature from day break to shot time. Blast time should be delayed to at least mid-morning to allow early morning temperature inversions, if present, to be eliminated.

The following are unfavorable atmospheric conditions for blasting:

(1) Foggy, hazy or smoky days with little or no wind or conditions associated with temperature inversion;

(2) During strong winds accompanying the passage of a cold front;

(3) During periods of the day when the surface temperature is falling;

(4) Too early in the morning or after sunset on clear days;

(5) Cloudy days with a low cloud ceiling, especially when there is little or no wind;

The following are methods of controlling air blast:

(1) Avoid the use of unconfined explosives;
- (a) Bury detonating cord one foot or more.
- (b) Use low-load detonating cord as possible.
- (c) Never adobe or mudcap in populated areas unless absolute necessary.

(2) Use adequate stemming;

(a) Use crushed stone for stemming in wet holes for better confinement and to avoid densifying water with drill fines so that low density charges may float.

(b) Use additional stemming on the front row if excessive backbreak from the previous shot is present.

(3) Maintain accurate drilling records;

(4) Use drill patterns having nearly equal burden to spacing ratios;

(5) Use a longer delay interval between rows than between holes in a row;

(6) Be sure the blast proceeds in the proper sequence;

(7) Consider geologic abnormalities;

(a) Use nonexplosive decks through mud-dirt seams, weak seams, etc.

(b) Have drillers report cavities which could be overloaded with explosives

(c) Check the drillers log to get an accurate analysis of all boreholes.

(8) Shot scheduling;

(a) Schedule shots at times when neighbors are busy, not at home and when they expect blasting to occur.

(b) Avoid early morning or very late afternoon blasts to reduce the possibility of blasting during temperature inversions.

(9) Consider weather conditions and take the appropriate precautions;

(10) Avoid excessive delays between holes;

(11) Consider beam formation when designing blasts.

(a) Minimize the number of opening holes having the same delay period.

(b) Avoid the use of long charges in boreholes whose length is large when compared with the burden of the hole.

GROUND VIBRATION

The public relations problem of ground vibration that is associated with the use of explosives is just as prevalent as the air blast problem. Once again, manufacturers, explosive consumers and government agencies have spent a vast amount of time and effort to gain a better understanding of ground vibration.

Blasters can overcome the complaints of vibration through careful blast design with the effective use of delays, by careful monitoring of the blast effects and by good, public relation meeting with neighbors to explain the care taken to protect their property and safety. In situations where complaints persist, continued attention to blast design, effective monitoring and good record keeping will be of invaluable importance.

When an explosive detonates in a borehole, it generates an intense stress wave in the surrounding rock. This wave crushes the rock that immediately represents the area of the blast fractured zone. When the intensity of the stress wave is reduced so that there is no permanent deformation of the rock, the wave propagates through the rock in an elastic manner in such a manner that the rock particles will return to their original position following passage of the stress wave. The stress waves travel through the earth causing rock particles to vibrate. Studies have shown that high frequency wave energy is absorbed more readily than low-frequency wave energy so that the energy content of stress waves at large distances is concentrated at low frequencies.

Various kinds of stress waves travel at different speeds and interact in a complicated manner with themselves and the material in which they travel. A blast that finishes detonating in a few hundred milliseconds or less can produce ground motion for several seconds at locations several hundred yards away. The lengthening of ground motion with distance is enhanced by a process known as dispersion whereby the different frequencies travel at different velocities.

The peak particle velocity of ground vibration depends on the maximum charge-weight-per-delay of eight milliseconds or more and not on the total weight of the blast.

All blast create ground vibration. As the stress wave (ground vibration) passes through a given area of ground, it causes that ground to vibrate. This situation is similar to the circular ripples produced on the surface of calm water when struck by a rock. Ground vibrations are measured with a seismograph machine. Vibrations are measured in terms of amplitude (size of the vibrations) and frequency (number of times that the ground moves back and forth in a given time period). Amplitude is usually measured in velocity in hertz or cycles per second. Excessively high ground vibration levels can damage domestic structures. Moderate to low levels of ground vibration can be irritating to neighbors and can cause complaints and or legal claims of damage and nuisance. The best protection against complaints and damage claims is good public relations. The blaster should inform local residents of the need and importance of blasting. A blaster should also stress the relative harmlessness of properly controlled blasting vibrations. Prompt and sincere response to complaints is absolutely vital.

Excessive ground vibrations are caused by either putting too much explosive energy into the ground or by not properly designing the shot. Part of the energy that is not used in fragmenting and displacing specific location is primarily determined by the maximum weight of explosives per delay period and the distance of that location from the closely spaced individual blasts. The longer the intervals between delays the better the separation will be between the individual blasts. Eight milliseconds is the minimum delay that can be used between charges if they are to be considered as separate charges for vibration purposes. In addition to charge weight per day, distance and delay interval, two other factors affect the level of ground vibration. The first factor is over confinement. A charge with a properly designed burden will produce less vibration. The second factor is an excessive amount of subdrilling. Excessive subdrilling will cause an extremely heavy confinement of explosive energy. In multiple row blasts, there is a tendency for the later rows to become over confined. To avoid this, it is often advisable to use longer delay periods between the later rows to give better relief.

Two vibration limits are important; the level above which damage is likely to occur and the level above which neighbors are likely to complain. There is no precise level at which damage begins to occur. The damage level depends on the type, condition, age of the structure, the type of ground on which the structure is built and the frequency of the vibration. People tend to complain about vibrations far below the damage level. The threshold of a complaint depends on complainant health, fear of damage, attitude toward the mining operation, diplomacy of the mine operator, how often and when blast are fired and the duration of the vibrations. The vibration tolerance level is very dependent on local attitude toward mining. Careful blast design and good public relations are essential elements for an operator to live in harmony with neighbors in order to minimize complaints and avoid legal claims.

Many mine operators prefer to seismograph every blast. Seismograph recordings are very useful in understanding and troubleshooting ground vibration problems. Seismograph records provide excellent evidence in case of later complaints or damage law suits.

Where vibrations are not a serious problem, a blaster may choose to use the scaled distance equation rather than measuring all blast vibrations with a seismograph. The scaled distance approach works well when the mine is an adequate distance from structures, vibrations are not a problem and the operator wants to save the expense of measuring vibrations. At close distances, though, the scaled distance approach becomes quite restricting in terms of allowable charge weight per delay and therefore monitoring is often a more economical option.

A seismograph is a special instrument that is used to measure particle motion that is associated with stress waves. The velocity type seismograph is the most widely used type for measuring ground motion generated by blasting operations. The velocity type seismograph records particle blasting operations. The velocity type seismograph records particle velocity of the stress wave at a particular location. Particle velocity is the rate of change in the stress wave amplitude as a function of time.

A seismograph will record the particle motion of stress waves in three mutually perpendicular directions. The three directions are longitudinal or horizontal, transverse, and vertical. Most seismographs are normally constructed to measure particle velocities ranging from .1 to 10 inches per second over a frequency range of 2 to 200 hertz or cycles per second.

The intensity of stress waves that can be tolerated by various kinds of structures must be established before acceptable charge weights at various distances can be determined. The level of motion required to damage a structure depends upon its construction. For example, a steel-framed building can tolerate a more intense stress wave than a residential structure with plastered walls. Because plaster is the weakest of the most commonly used materials for construction and because of the prevalence of such structures, damage criteria is based on this type structure. Blasters may consult structural engineers who are able to specify permitted vibration levels for certain types or kinds of structures.

The following is a list of steps that a blaster can take to help reduce ground vibration:

(1) Use a blast design that produces the maximum relief that is practical. Explosions in boreholes which have good relief and those having nearby free faces produce less ground vibration. The use of delay blasting techniques establish internal free faces which reduces ground vibration. The proper design of delay patterns can help achieve maximum relief. In general when blasting multiple row patterns, greater relief can be obtained by using a greater delay time between rows than between holes in a single row. A delay time between holes in a row of at least one millisecond per foot of burden is usually recommended for the necessary relief and maximum fragmentation;

(2) Use the proper powder factor. An excessive powder factor will usually increase both ground vibration and air blast and may cause excessive burden displacement or fly rock. On the other hand, an insufficient powder factor will usually increase ground vibration by delaying or reducing the effect of stress waves reflected off the free faces. The optimum powder factor must be determined by experimentation at any given blasting site and used;

(3) Use a spacing-to-burden ratio equal to or greater than one, if possible. The presence of weak seams or irregular backbreak may dictate the use of a spacing-to-burden ratio less than one;

(4) Control drilling of blast holes as closely as possible. A blaster should establish bench marks for use in setting out hole locations of the next blast before the blast is made to help avoid possible error because of irregular backbreak;

(5) Keep the amount of subdrilling to the minimum required to maintain good floor conditions. A typical amount of subdrilling is .3 times the burden at floor level. Excessive subdrilling will usually increase ground vibration because of high confinement and a lack of a nearby free face;

(6) Use various techniques to reduce charge-weight-per-delay which should in turn reduce the peak particle velocity;

(a) Reduce hole depths and reduce bench heights.

(b) Use smaller diameter holes.

(c) Subdivide explosive charges in hole by using inert decks and fire each explosives deck with an initiator of a different delay period.

(d) Use electronic timers to increase the available number of delay periods of electric blasting caps and to increase timing flexibility. Sequential timers are used for this purpose and are real effective in helping to shorten the duration of ground motion.

(7) Use delay electric blasting caps or surface connectors to reduce the number of holes on a delay period when excessive ground vibration is caused by Presplitting shots.

UNIT XII

COAL MINE SAFETY LAWS OF VIRGINIA

STORAGE OF DETONATORS AND EXPLOSIVES

Separate surface magazines shall be provided for the storage of explosives and detonators.

Surface magazines for storing and distributing explosives in amounts exceeding one hundred fifty pounds shall be:

(1) Reasonably bulletproof and constructed of incombustible material or covered with fire-resistive material. The roofs of magazines so located that it is impossible to fire bullets directly through the roof from the ground, need not be bulletproof, but where it is possible to fire bullets directly through them, roofs shall be made bullet-resistant by material construction, or by a ceiling that forms a tray containing not less than a four-inch thickness of sand, or by other methods.

(2) Provided with doors constructed of three-eighth inch steel plate lined with a two-inch thickness of wood, or the equivalent.

(3) Provided with dry floors made of wood or other nonsparking material and have no metal exposed inside the magazine.

(4) Provided with suitable warning signs so located that a bullet passing directly through the face of a sign will not strike the magazine.

(5) Provided with properly screened ventilators.

(6) Equipped with no openings except for entrance and ventilation.

(7) Kept locked securely when unattended.

Surface magazines for storing detonators need not be bulletproof, but they shall be in accordance with other provisions for storing explosives.

Explosives in amounts of one hundred fifty pounds or less or five thousand detonators or less shall be stored accordance with preceding standards or in separate locked box-type magazines. Box-type magazines may also be used as distributing magazines when quantities do not exceed those mentioned. Box-type magazines shall be constructed strongly of two-inch hardwood or the equivalent. Metal magazines shall be lined with nonsparking material. No magazine shall be placed in a building containing oil, grease, gasoline, wastepaper or other highly flammable material; nor shall a magazine be placed within twenty feet of a stove, furnace, open fire or flame.

The location of magazines shall be not less than three hundred feet from any mine opening, occupied building or public road or any road which the Chief designates in order to promote safety. However, in the event that a magazine cannot be practicably located at such a distance, if sufficiently barricaded and approved by the Chief, such magazine may be located less than three hundred feet from any mine opening, occupied building or road.

The supply kept in distribution magazines shall be limited to approximately a forty-eight hour supply, and such supplies of explosives and detonators may be distributed from the magazine, if separated by at least a four-inch substantially fastened hardwood partition or the equivalent.

The area surrounding magazines for not less than twenty-five feet in all directions shall be kept free of rubbish, dry grass or other materials of a combustible nature.

If the explosives magazine is illuminated electrically, the lamps shall be of vapor-proof type, installed and wired so as to present minimum fire and contact hazards.

Only nonmetallic tools shall be used for opening wooden containers. Extraneous materials shall not be stored in an explosives or detonator magazine.

Smoking, carrying smokers' articles or open flames shall be prohibited in or near any magazine.

MISFIRES

A. Misfires shall be reported promptly to the mine foreman and no other work shall be performed in the blasting area until the hazard has been corrected. A waiting period of at least fifteen minutes shall elapse before anyone returns to the misfired holes. If explosives are suspected of burning in a hole, all persons affected shall move to a safe location for the longer of one hour or until the danger has passed. When such failure involves electronic detonators, the blasting cable shall be disconnected from the source of power and the battery ends short-circuited before electric connections are examined.

B. Explosives shall be removed by firing a separate charge at least two feet away from, and parallel to, the misfired charge or by washing the stemming and the charge from the borehole with water, or by inserting and firing and new primer after the stemming has been washed out.

C. A very careful search of the blasting area, and if necessary, of the coal after it reaches the tipple shall be made after blasting a misfired hole to recover any undetonated explosive.

D. The handling of a misfired shot shall be under the direct supervision of the foreman or an authorized person designated by him.

UNIT XIII

INSTRUCTIONS AND WARNINGS

INSTRUCTIONS AND WARNINGS

DRILLING

Good drilling practices are not only essential to good blasting results but also necessary for the conduct of a safe blasting operation.

There are three commonly used drill patterns: square, rectangular and staggered. The square pattern has equal burdens and spacings. The rectangular pattern has a larger spacing than burden. In both the square and rectangular patterns, the holes of each row are lined up directly behind the holes in the preceding row. In the staggered pattern, the holes in each row are located in the middle of the spacings of the holes in the preceding row. In the staggered pattern, the spacing should be larger than the burden.

The staggered pattern is used for row-on-row firing where the holes of one row are fired before the holes in the row immediately behind them. The square or rectangular patterns are used for firing V-cuts. In a V-cut, the burdens and subsequent rock displacement are at an angle to the original free face. These three patterns account for the vast majority of surface blasts.

The following factors must be considered in selecting a drill pattern:

(1) Geology – This type of rock and overburden are very important. If the overburden rock is sandstone, limestone or other massive hard-to-break rock, then the burden and spacing should be smaller than if the overburden material is shale, slate or other easy-to-break rock;

(2) Fragmentation desired – The desired fragmentation is dependent upon the type of equipment used for removal. If the equipment can handle large rock pieces, then a larger burden and spacing can be more economical. If the equipment is only capable of handling smaller material, then more fragmentation is necessary that would enhance the use of smaller burdens and spacings;

(3) Diameter of the borehole – The borehole diameter, hence the diameter of the explosive material placed in the borehole is the most important factor in determining a drill pattern. Small diameter holes require closer spacing than large diameter holes;

(4) Type of Explosive – The type of explosive has a great influence on the pattern. ANFO is the most widely used blasting explosive mainly because of cost per volume of broken material. Dynamite will break a larger volume of rock but is not as economical or safe as ANFO to use. ANFO charged holes would be closer than for dynamite charged holes. The type of explosive or blasting agent for the main charge is mainly dependent upon borehole condition, namely whether the boreholes are dry or wet. Bulk ANFO is mainly used for dry holes. Wet hole bags or borehole liners have to be used in wet boreholes;

(5) Depth of holes – The burden should never be greater than the depth. Deeper boreholes, generally, will enable an expanded pattern and still yield good fragmentation. A blaster must recognize that a considerable amount of design is based on past experience in blasting the applicable area. Different sites have different characteristics. A certain amount of trial-and-error is truly involved. The design factors are closely related to each other and changing one factor will affect the others;

(6) Accurate drill design – The driller must follow the selected drill pattern accurately. If the holes are not drilled in the correct places, then the result could be blowouts, flyrock, air blast, ground vibration and wasted explosive energy. Poor fragmentation will put an added strain on the mining equipment at an added cost and loss of removal efficiency.

Drilling into explosives is one of the most frequent causes of blasting accidents. The best way to eliminate drilling accidents involving explosives is to make sure that all explosives loaded in the previous blast were detonated. Poorly drilled shot patterns can also cause cutoffs, fly rock and poor fragmentation.

After every blast and before the drilling begins, the area must be thoroughly inspected for undetonated explosives. A driller must never drill into explosives or into any hole that has contained explosives.

CLEARING A BLAST AREA

Adequate precautions must always be taken to clear a blast area to insure the safety of mining personnel and the general public. A predetermined plan should be prepared for clearing the blast area of personnel and equipment.

A blast area must be cleared of all unnecessary personnel and equipment. Place any required stemming material in a convenient spot in the blast area before any explosives are delivered for loading. No activity of a continuous nature such as the operation of equipment should be permitted in the area where explosives are being loaded.

The blaster in charge must never assume that a blast area is clear. The blaster in charge must always make absolutely certain without any doubt that a blast area is clear. The majority of injuries from explosives occur because the blast area was not properly cleared. Fly rock can result in injuries a remarkable distance from the blast area.

A blaster must always remember that the public is curious and could enter the danger zone of a blast area. The blaster in charge must always conduct a very thorough and accurate clearing of a blast area.

Loose highwalls or other unstable conditions may present a hazard because of vibrations that could occur from the blast. These areas must also be cleared of all personnel and avoided during the blast.

No person should be allowed to be in front of a blast. Routine blasts that may be considered safe have been known to throw fly rock many times the distance that has been thrown in the past.

GUARDING A BLAST AREA

A predetermined plan should be prepared in order to properly execute the guarding of a blast area.

Guards should be posted to block all access roads and all other areas where a blaster may suspect the unauthorized entry of any person. The blaster in charge must be certain that the guards are posted a sufficient distance from the blast area to be safe from any possible fly rock. The guards must be informed when they are to stop all traffic, without any exceptions. The guards must understand that all traffic must be stopped. All guards should have a method of communicating with the blaster in charge. A blaster must remember that in this day of hikers, trail bikes, etc. that a road may not be the only access to a blast area. Special guards may be necessary to solve these special types of problems. The blaster in charge must always make certain that a blast area has been properly cleared and guarded before firing.

A signaling system known to all personnel must be a vital part of any safe blasting program. This system should provide ample time between the time when it is sounded and the actual firing time. Usually, the first signal is at five minutes prior to the actual blast time. At this time, all guards should report and the blaster in charge should know the exact location of all personnel. At one minute before blast time another signal is sounded and radio silence should be observed. The radio channel must be left open under complete silence so that the blast could be stopped by any guard who may observe an unsafe condition or unauthorized entry.

The blaster in charge who is responsible for firing the blast must be in a safe position. The blaster must not only be protected from direct fly rock but also rolling or ricocheting rock. A location under a piece of heavy equipment will not offer protection from rolling or ricocheting rock.

After the blast, all guards and mining personnel must remain in their positions until the “all clear” signal is sounded.

HIGHWALL SAFETY

Falling or rolling rock hazards present a potentially hazardous situation. Many tons of rock or loose material may be left hanging loosely in the area after the blast. This material may fall, without warning, that could seriously injure or kill mining personnel.

In every blasting operation, the blaster in charge and the surface foreman must make certain that the previous shot did not produce any new or unforeseen hazards. Before returning personnel and equipment into an area recently blasted, the responsible personnel must wait until the postblast smoke and fume level is safe. Smoke from a blast could obscure dangerous conditions including toxic fumes, burning explosive, unstable material, falling rock, etc. The blaster in charge and surface foreman must make sure that no person enters the postblast smoke for the above reasons.

The blaster in charge and surface foreman must also inspect the blast results for undetonated explosives and recognize possible highwall hazards created by the blast. They must also evaluate, recognize and correct hazardous falling rock conditions and other highwall hazards.

As the blaster in charge and surface foreman are entering a postblast area, the first hazard that they should observe on their approach is loose rock, loose material, weak wall conditions, wall partings, etc. They should also look for conditions or indications of a possible rock slide. Many tons of rock and or material have fallen onto pit areas without warning from a few seconds to several days after a blast. The blaster in charge and surface foreman must make certain that geological hazards such as wall partings or weak seams which might release the highwall face are detected and managed properly. Weak vertical planes present an unpredictable hazard and should be avoided by all mining personnel. If weak vertical planes are present, then design the next blast well beyond these planes.

UNIT XIV
VIRGINIA COAL SURFACE MINING CONTROL RECLAMATION ACT OF 1979 AND COAL SURFACE MINING RECLAMATION REGULATIONS

The following are provisions of the “Virginia Coal Surface Mining Control and Reclamation Act of 1979 as required by the Federal Surface Mining Control and Reclamation Act of 1977 and which are enforced by the Division of Mined Land Reclamation (DMLR).

4 VAC 25-130-780.13 Operation Plan: Blasting

(a) Blasting plan. Each application shall contain a blasting plan for the proposed permit area, explaining how the applicant will comply with the requirements of 4 VAC 25-130-816.61, 4 VAC 25-130-816.68. This plan shall include, at a minimum, information setting forth the limitations the permittee will meet with regard to ground vibration and airblast, the basis for those limitations, and the methods to be applied in controlling the adverse effects of blasting operations.

(b) Monitoring system. Each application shall contain a description of any system to be used to monitor compliance with the standards of 4 VAC 25-130-816.67 including the type, capability, and sensitivity of any blast-monitoring equipment and proposed procedures and locations of monitoring.

(c) Blasting near underground mines. Blasting operations within 500 feet of active underground mines require approval of the State and Federal regulatory authorities concerned with the health and safety of underground miners.

4 VAC 25-130-780.14 Operational Plan: Maps and Plans

Each application shall contain maps and plans as follows:

(a) The maps and plans shall show the land proposed to be affected throughout the operation and any change in a facility or feature to be caused by the proposed operations, if the facility or feature was shown under 4 VAC 25-130-779.24 through 4 VAC 25-130-779.25.

(b) The following shall be shown for the proposed permit area:

(1) Buildings, utility corridors and facilities to be used;
(2) The area of land to be affected within the proposed permit area, according to the sequence of mining and reclamation;
(3) Each area of land for which a performance bond or other equivalent guarantee will be posted under Subchapter VJ;
(4) Each coal storage, cleaning and loading area;
(5) Each topsoil, spoil, coal waste, and non-coal waste storage area;
(6) Each water diversion, collection, conveyance, treatment storage, and discharge facility to be used;
(7) Each source of waste and each waste disposal facility relating to coal processing or pollution control;
(8) Each facility to be used to protect and enhance fish and wildlife and related environmental values;
(9) Each explosive storage and handling facility; and
(10) Location of each sedimentation pond, permanent water impoundment, coal processing waste bank, and coal processing waste dam and embankment, in accordance with 4 VAC 25-130-780.25 and fill area for the disposal of excess spoil in accordance with 4 VAC 25-130-780.35.

(c) Maps, plans, and cross sections required under Paragraphs (b) (4), (5), (6), (9) and (10), shall be prepared by, or under the direction of, and certified by a qualified registered professional engineer, or certified professional geologist, with the assistance from experts in related fields, such as land surveying and landscape architecture, except that - -

(1) Maps, plans, and cross sections for sedimentation ponds may only be prepared by a qualified registered professional engineer; and
(2) Maps, plans, and cross sections of spoil disposal facilities may only be prepared by a qualified registered professional engineer.

4 VAC 25-130-816.61 Use of Explosives: General Requirements

(a) Compliance with other laws. Each permittee shall comply with all applicable State and Federal laws and regulations in the use of explosives.

(b) Blasting schedule. Blasts that use more than 5 pounds of explosive or blasting agent shall be conducted according to the schedule required under 4 VAC 25-130-816.54.

(c) Blasters.
(1) All blasting operations in the State shall be conducted under the direction of a certified blaster certified in accordance with Part 4 VAC 25-130-850.

(2) Certificates of blasters certification shall be carried by blasters or shall be on file at the permit area during blasting operations.

(3) A blaster and at least one other person shall be present at the firing of a blast.

(4) Persons responsible for blasting operations at a blasting site shall be familiar with the blasting plan and site-specific performance standards.

(d) Blast design.
(1) An anticipated blast design shall be submitted if blasting operations will be conducted within -
(i) 1000 feet of any building used as a dwelling, public building, school, church, or community or institutional building outside the permit area; or
(ii) 500 feet of an active or abandoned underground mine.

(2) The blast design may be presented as a part of a permit application or at a time, before the blast, proposed in the application and approved by the Division.

(3) The blast design shall contain sketches of the drill patterns, delay periods, and decking and shall indicate the type and amount of explosives to be used, critical dimensions, and the location and general description of structures to be protected as well as a discussion of design factors to be used, which protect the public and meet the applicable airblast, flyrock, and ground vibration standards in 4 VAC 25-130-816.67.

(4) At least thirty days before initiation of blasting, the permittee shall notify, in writing, all residents or owners of dwellings or other structures located within ½ mile of the permit area how to request a preblasting survey.

(5) The Division may require changes to the design submitted.

4 VAC 25-130-816.62 Use of Explosives: Preblasting Survey

(a) At least thirty days before initiation of blasting, the permittee shall notify, in writing, all residents or owners of dwellings or other structures located within ½ mile of the permit area how to request a preblasting survey.

(b) A resident or owner of a dwelling or structure within ½ mile of any part of the permit area may request a preblasting survey. This request shall be made, in writing, directly to the permittee or to the Division, who shall promptly notify the permittee. The permittee shall promptly conduct a preblasting survey of the dwelling or structure and promptly prepare a written report of the survey. An updated survey of any additions, modifications, or renovations shall be performed by the permittee if requested by the resident or owner. The request for an updated survey shall be in writing and describe the additions, modifications, or renovations which are to be surveyed.

(c) The permittee shall determine the condition of the dwelling or structure and shall document any preblasting damage and other physical factors that could reasonably be affected by the physical factors that could reasonably be affected by the blasting. Structures such as pipelines, cables, transmission blasting. Structures such as pipelines, cables, transmission lines, and cisterns, wells, and other water systems warrant any special attention; however, the assessment of these structures may be limited to surface conditions and other readily available data.

(d) The written report of the survey shall be signed by the person who conducted the survey. Copies of the report shall be promptly provided to the Division and to the person requesting the survey. If the person requesting the survey disagrees with the contents and/or recommendations contained therein, he may submit to both the permittee and the Division a detailed description of the specific areas of disagreement.

(e) Any surveys requested more than 10 days before the planned initiation of blasting shall be completed by the permittee before the initiation of blasting. Any surveys requested after permit approval but less than 10 days before the planned initiation of blasting shall be completed by the permittee within 30 days of the request, except that reasonable time extensions may be approved by the Division.

4 VAC 25-130-816.64 Use of Explosives: Blasting Schedule

(a) General requirements.

(1) The permittee shall conduct blasting operations at times approved by the Division and announced in the blasting schedule. The Division may limit the area covered, timing, and sequence of blasting as listed in the schedule, if such limitations are necessary and reasonable in order to protect the public health and safety or welfare.

(2) All blasting shall be conducted during daylight hours. The Division may specify more restrictive time periods for blasting.

(3) Unscheduled blasts may be conducted only where public or permittee health and safety so require and for emergency blasting actions. When a permittee conducts an unscheduled blast, the permittee, using audible signals, shall notify residents within ½ mile of the blasting site and document the reason for the unscheduled blast in accordance with 4 VAC 25-130-816.68 (p).

(b) Blasting schedule publication and distribution.

(1) The permittee shall publish the blasting schedule in a newspaper of general circulation in the locality of the blasting site at least 10 days, but not more than 30 days, before beginning a blasting program.

(2) The permittee shall distribute copies of the schedule to local governments and public utilities and to each local residence within ½ mile of the proposed blasting site described in the schedule.

(3) The permittee shall republish and redistribute the schedule at least every 12 months and revise and republish the schedule at least 10 days, but not more than 30 days, before blasting whenever the area covered by the schedule changes or actual time periods for blasting significantly differ from the prior announcement.

(c) Blasting schedule contents. The blasting schedule shall contain, at a minimum:

(1) Name, address, and telephone number of the permittee;

(2) Identification of the specified areas in which blasting will take place;

(3) Dates and time periods when explosives are to be detonated;

(4) Methods to be used to control access to the blasting area; and

(5) Type and patterns of audible warning and all-clear signals to be used before and after blasting.

4 VAC 25-130-816.66 Use of Explosives: Blasting Signs, Warning, and Access Control

(a) Blasting signs. Blasting signs shall meet the specifications of 4 VAC 25-130-816.11.

a. Specifications. Signs and markers required in this part shall - -
   1. Be posted, maintained, and removed by the person who conducts the surface mining activities;
   2. Be of a uniform design throughout the operation that can be easily seen and read;
   3. Be made of durable material; and
   4. Conform to local ordinances and codes.

b. Maintenance. Signs and markers shall be maintained during the conduct of all activities to which they pertain.

c. Mine and permit identification signs.
   1. Identification signs shall be displayed at each point of access to the permit area from public roads.
   2. Signs shall show the name, business address, and telephone number of the current permit authorizing surface coal mining activities.
   3. Signs shall be retained and maintained until after the release of all bonds for the permit area.

d. Perimeter markers. The perimeter of a permit area shall be clearly marked prior to the permit review conducted by the division's field enforcement personnel. The boundaries shall be clearly marked by flagging, stakes or signs as required under 4 VAC 25-130-816.57. all markers shall be easily visible from adjacent markers. The approximate outer perimeter of the solid portion of any pre-existing bench shall be closely marked prior to permit review.

e. Buffer zone markers. Buffer zones shall be marked along their boundaries, prior to permit review conducted by the division's field enforcement personnel. The boundaries shall be clearly marked by flagging, stakes or signs. All markers shall be easily visible from adjacent markers. The approximate outer perimeter of the solid portion of any pre-existing bench shall be closely marked prior to permit review.

f. Blasting signs. If blasting is conducted incident to surface mining activities, the person who conducts these activities shall:
   1. Conspicuously place signs reading "Blasting Area" along the edge of any blasting area that comes within 100 feet of any public road right of way, and at the point where any other road provides access to the blasting area; and

2. At all entrances to the permit area from public roads or highways place conspicuous signs which state "Warning! Explosives in Use" which clearly list and describe the meaning of the audible blasting warning and all clear signals that are in use, and which explain the marking of blasting areas and charged holes awaiting firing within the permit area.

g. Topsoil markers. Where topsoil or other vegetation – supporting material is segregated and stockpiled as required under 4 VAC 25-130-816.22, the stockpiled material shall be clearly marked.

h. Incremental bonding markers. When the permittee elects to increment the amount of performance bond during the term of the permit, he shall, if required by the division, identify the initial and successive incremental areas for bonding by clearly marking such areas (with markers different from the perimeter markers) prior to disturbing the incremental area(s).

(b) Warnings. Warnings and all-clear signals of different character or pattern that are audible within a range of ½ mile from the point of the blast shall be given. Each person within the permit area and each person who resides or regularly works within ½ mile of the permit area shall be notified of the meaning of the signals in the blasting schedule.

(c) Access control. Access within the blasting area shall be controlled to prevent presence of livestock or unauthorized person during blasting and until an authorized representative of the permittee has reasonably determined that -

(1) No unusual hazards, such as imminent slides or undetonated charges, exist; and
(2) Access to and travel within the blasting area can be safely resumed.

4 VAC 25-130-816.67 Use of Explosives: Control of Adverse Effects

(a) General requirements. Blasting shall be conducted to prevent injury to persons, damage to public or private property outside the permit area, adverse impacts on any underground mine, and change in the course, channel, or availability of surface or ground water outside the permit area.

(b) Airblast.

(1) Limits.

(i) Airblast shall not exceed the maximum limits listed below at the location of any dwelling, public building, school, church, or community or institutional building outside the permit area, except as provided in Paragraph (e) of this Section.

Lower frequency limit of measuring System, in Hz (+3 dB)	Maximum level, in db
0.1 Hz or lower – flat response[1]	134 peak
2 Hz or lower – flat response	133 peak
6 Hz or lower – flat response	129 peak
C – Weighted – slow response[1]	105 peak

1 Only when approved by the Division

(ii) If necessary to prevent damage, the Division shall specify lower maximum allowable airblast levels than those of Paragraph (b) (1) (i) of this Section for use in the vicinity of a specific blasting operation.

(2) Monitoring.

(i) The permittee shall conduct periodic monitoring to ensure compliance with the airblast standards. The Division may require airblast measurement of any or all blasts and may specify the locations at which such measurements are taken.

(ii) The measuring systems shall have an upper-end flat-frequency response of at least 200 Hz.

(c) Flyrock. Flyrock travelling in the air or along the ground shall not be cast from the blasting site –

(1) More than one-half of the distance to the nearest dwelling or other occupied structure;

(2) Beyond the area of control required under 480-03-19.816.66 (c); or

(3) Beyond the permit boundary.

(d) Ground vibration.

(1) General. In all blasting operations, except as otherwise authorized in Paragraph (e) of this Section, the maximum ground vibration shall not exceed the values approved in the blasting plan required under 480-03-19.780.13. The maximum ground vibration for protected structures listed in Paragraph (d) (2) (i) of this Section shall be established in accordance with either the maximum peak-particle-velocity limits of Paragraph (d) (2), the scaled distance equation of Paragraph (d) (3), the blasting-level chart of Paragraph (d) (4), or by the Division under Paragraph (d) (5) of this Section. All structures in the vicinity of the blasting area, not listed in Paragraph (d) (2) (i), of this Section, such as water towers, pipelines and other utilities, tunnels, dams, impoundments, and underground mines, shall be protected from damage by establishment of a maximum allowable limit on the ground vibration, submitted by the permittee in the blasting plan and approved by the Division.

(2) Maximum peak particle velocity.

(i) The maximum ground vibration shall not exceed the following limits at the location of any dwelling, public building, school, church, or community or institutional building outside the permit area:

Distance (D), from the Blasting site, in feet	Maximum Allowable peak particle Velocity (Vmax) for ground vibration, in inches/second[1]	Scaled distance factor to be applied without seismic monitoring[2] (Ds)
0 to 300	1.25	50
301 to 5,000	1.00	55
5,001 and beyond	0.75	65

[1]Ground vibration shall be measured as the particle velocity. Particle velocity shall be recorded in three mutually perpendicular directions. The maximum allowable peak particle velocity shall apply to each of the three measurements.

[2]Applicable to the scaled-distance equation of Paragraph (d) (3) (i) of this Section.

(ii) A seismographic record shall be provided for each blast.

(3) Scale-distance equation.

(i) The permittee may use the scaled distance equation, $W = (D/Ds)^2$, to determine the allowable charge weight of explosives to be detonated in any 8-millisecond period, without seismic monitoring; where W = the maximum weight of explosives, in pounds; D = the distance, in feet, from the blasting site to the nearest protected structure; and Ds = the scaled-distance factor, which may initially be approved by the Division using the values for scaled-distance factor listed in Paragraph (d) (2) (i) of this Section.

(ii) The development of a modified scaled-distance factor may be authorized by the Division on receipt of a written request by the permittee, supported by seismographic records of blasting at the mine site. The modified scale-distance factor shall be determined such that the particle velocity of the predicted ground vibration will not exceed the prescribed maximum allowable peak particle velocity of Paragraph (d) (2) (1) of this Section at a 95-percent confidence level.

(4) Blasting-level chart.

(i) the permittee may use the ground-vibration limits in Figure 1 to determine the maximum allowable ground vibration.

(ii) If the Figure 1 limits are used, a seismographic record including both particle velocity and vibration-frequency levels shall be provided for each blast. The method for the analysis of the predominant frequency contained in the blasting records shall be approved by the Division before application of this alternative blasting criterion.

(5) The maximum allowable ground vibration shall be reduced by the Division below the limits otherwise provided by this Section, if determined necessary to provide damage protection.

(6) The Division may require the permittee to conduct seismic monitoring of any or all blasts or may specify the location at which the measurements are taken and the degree of detail necessary in the measurement.

(d) The maximum airblast and ground vibration standards of Paragraphs (b) and (d) of this Section shall not apply at the following locations:

(1) At structures owned by the permittee and not leased to another person.

(2) At structures owned by the permittee and leased to another person, if a written waiver by the lessee is submitted to the Division before blasting.

4 VAC 25-130-816.68 Use of Explosives: Records of Blasting Operations

The permittee shall retain a record of all blasts for at least 3 years. Upon request, copies of these records shall be made available to the Division and to the public for inspection. Such records shall contain the following data:

(a) Name of the permittee conducting the blast;

(b) Location, date, and time of the blast;

(c) Name, signature, and certification number of the blaster conducting the blast;

(d) Identification, direction, and distance, in feet, from the nearest blast hole to the nearest dwelling, public building, school, church, community or institutional building outside the permit area, except those described in 480-03-19.816.67 (e);

(e) Weather conditions, including those which may cause possible adverse blasting effects;

(f) Type of material blasted;

(g) Sketches of the blast pattern including number of holes, burden, spacing, decks, and delay pattern;

(h) Diameter and depth of holes;

(i) Types of explosives used;

(j) Total weight of explosives used per hole;

(k) The maximum weight of explosives detonated in an 8-millisecond period;

(l) Initiation system;

(m) Type and length of stemming;

(n) Mats or other protections used;

(o) Seismographic and airblast records, if required, which shall include:

(1) Type of instrument, sensitivity, and calibration signal or certification of annual calibration;

(2) Exact location of instrument and the date, time, and distance from the blast;

(3) Name of the person and firm taking the reading;

(4) Name of the person and firm analyzing the seismographic record; and

(5) The vibration and/or airblast level recorded.

(p) Reasons and conditions for each unscheduled blast.

4 VAC 25-130-817.61 Use of Explosives: General Requirements

(a) Applicability. 4 VAC 25-130-817.61 through 4 VAC 25-130-817.68 apply to surface blasting activities incident to underground coal mining, including, but not limited to, initial rounds of slopes and shafts.

(b) Compliance with other laws. Each permittee shall comply with all applicable State and Federal laws and regulations in the use of explosives.

(c) Blasters.

(1)All surface blasting operations incident to underground mining in the State shall be conducted under the direction of a certified blaster, certified in accordance with – Part 4 VAC 25-130-850.

(2) Certificates of blaster certification shall be carried by blasters or shall be on file at the permit area during blasting operations.

(3) A blaster and at least one other person shall be present at the firing of a blast.

(4) Persons responsible for blasting operations at a blasting site shall be familiar with the blasting plan and site-specific performance standards.

(d) Blast design.

(1) An anticipated blast design shall be submitted if blasting operations will be conducted within:

(i) 1,000 feet of any building used as a dwelling, public building, school, church or community or institutional building; or

(ii) 500 feet of active or abandoned underground mines.

(2) The blast design may be presented as a part of a permit application or at a time, before the blast, proposed in the application and approved by the Division.

(3) The blast design shall contain sketches of the drill patterns, delay periods, and decking and shall indicate the type and amount of explosives to be used, critical dimensions, and the location and general description of structures to be protected, as well as a discussion of design factors to be used, which protect the public and meet the applicable airblast, flyrock, and ground vibration standards in 4 VAC 25-130-817.67.

(4) The blast design shall be prepared and signed by a certified blaster.

(5) The Division may require changes to the design submitted.

4 VAC 25-130-817.62 Use of Explosives: Preblasting Survey

(a) At least 30 days before initiation of blasting, the permittee shall notify, in writing, all residents or owners of dwellings or other structures located within ½ mile of the permit area on how to request a preblast survey.

(b) A resident or owner of a dwelling or structure within ½ mile of any part of the permit area may request a preblasting survey. This request shall be made, in writing, directly to the permittee or to the Division, who shall promptly notify the permittee. The permittee shall promptly conduct a preblasting survey of the dwelling or structure and promptly prepare a written report of the survey. An updated survey of any additions, modifications, or renovations shall be performed by the permittee if requested by the resident or owner. The request for an updated survey shall be in writing and describe the additions, modifications, or renovations which are to be surveyed.

(c) The permittee shall determine the condition of the dwelling or structure and shall document any preblasting damage and other physical factors that could reasonably be affected by the blasting. Structures such as pipelines, cables, transmission lines, cisterns, wells, and other water systems warrant special attention; however, the assessment of these structures may be limited to surface conditions and other readily available data.

(d) The written report of the survey shall be signed by the person who conducted the survey. Copies of the report shall be promptly provided to the Division and to the person requesting the survey. If the person requesting the survey disagrees with the contents and/or recommendations contained therein, he may submit to both the permittee and the Division and detailed description of the specific areas of disagreement.

(e) Any surveys requested more than 10 days before the planned initiation of blasting shall be completed by the permittee before the initiation of blasting. Any surveys requested after permit approval but less than 10 days before the planned initiation of blasting shall be completed by the permittee within 30 days of the request, except that reasonable time extensions may be approved by the Division.

4 VAC 25-130-817.64 Use of Explosives: General Performance Standards

(a) The permittee shall notify, in writing, residents within ½ mile of the blasting site and local governments of the proposed times and locations of blasting operations. Such notice of times that blasting is to be conducted may be announced weekly, but in no case less than 24 hours before blasting will occur.

(b) Unscheduled blasts may be conducted only where public or permittee health and safety so requires and for emergency blasting actions. When a permittee conducts an unscheduled surface blast incidental to underground coal mining operations, the permittee, using audible signals, shall notify residents within ½ mile of the blasting site and document the reason in accordance with 4 VAC 25-130-817.68 (P).

(c) All blasting shall be conducted during daylight hours. The Division may specify more restrictive time periods for blasting.

4 VAC 25-130-817.66 Use of Explosives: Blasting Signs, Warnings, and Access Control

(a) Blasting signs. Blasting signs shall meet the specifications of 4 VAC 25-130-816.11, as described under 4 VAC 25-130-816.66.

(b) Warnings. Warnings and all clear signals of different character or pattern that are audible within a range of ½ mile from the point of the blast shall be given. Each person within the permit area and each person who resides or regularly works within ½ mile of the permit area shall be notified of the meaning of the signals in the blasting notification required in 4 VAC 25-130-817.64(a).

(c) Access control. Access within the blasting area shall be controlled to prevent presence of livestock or unauthorized persons during blasting, and until an authorized representative of the permittee has reasonably determined that:

(1) No unusual hazards, such as imminent slides or undetonated charges, exist; and

(2) Access to and travel within the blasting area can be safely resumed.

4 VAC 25-130-817.67 Use of Explosives: Control of Adverse Effects

(a) General requirements. Blasting shall be conducted to prevent injury to persons, damage to public or private property outside the permit area, adverse impacts on any underground mine, and change in the course, channel, or availability of surface or ground water outside the permit area.

(b) Airblast.

(1) Limits.

(i) Airblast shall not exceed the maximum limits listed below at the location of any dwelling, public building, school, church or community or institutional building outside the permit area, except as provided in Paragraph (e) of this Section.

Lower frequency limit of measuring System, in Hz (±3 dB)	Maximum level, in dB
0.1 Hz or lower – flat response	134 peak
2 Hz or lower – flat response	133 peak
6 Hz or lower – flat response	129 peak
C-weighted – slow response	105 peak

1 Only when approved by the Division

(ii) If necessary to prevent damage, the Division shall specify lower maximum allowable airblast levels than those of Paragraph (b) (l) (i) of this Section for use in the vicinity of a specific blasting operation.

(2) Monitoring.

(i) The permittee shall conduct periodic monitoring to ensure compliance with the airblast standards. The Division may require airblast measurement of any or all blasts and may specify the locations at which such measurements are taken.

(ii) The measuring system shall have an upper-end flat-frequency response of at least 200 Hz.

(c) Flyrock. Flyrock traveling in the air or along the ground shall not be cast from the blasting site:

(1) More than one-half of the distance to the nearest dwelling or other occupied structure;

(2) Beyond the area of control required under 480-03-19.816.66 (c); or

(3) Beyond the permit boundary.

(d) Ground vibration.

(1) General. In all blasting operations, except as otherwise authorized in Paragraph (e) of this Section, the maximum ground vibration shall not exceed the values approved by the Division. The maximum ground vibration for protected structures listed in Paragraph (d) (2) (i) of this Section shall be established in accordance with either the maximum peak-particle velocity limits of Paragraph (d) (2), the scaled distance equation of Paragraph (d) (3), the blasting-level chart of Paragraph (d) (4), or by the Division under Paragraph (d) (5) of this Section. All structures in the vicinity of the blasting area, not listed in Paragraph (d) (2) (i) of this Section, such as water towers, pipelines and other utilities, tunnels, dams, impoundments, and underground mines, shall be protected from damage by establishment of a maximum allowable limit on the ground vibration, submitted by the permittee in the blasting plan and approved by the division before the initiation of blasting.

(2) Maximum peak particle velocity.

(i) the maximum ground vibration shall not exceed the following limits at the location of any dwelling, public building, school, church, or community or institutional building outside the permit area:

Distance (D), from the Blasting site, in feet	Maximum Allowable peak particle Velocity (Vmax) for ground vibration, in inches/second[1]	Scaled distance factor to be applied without seismic monitoring[2] (Ds)
0 to 300	1.25	50
301 to 5,000	1.00	55
5,001 and beyond	0.75	65

[1] Ground vibration shall be measured as the particle velocity. Particle velocity shall be recorded in three mutually perpendicular directions. The maximum allowable peak particle velocity shall apply to each of the three measurements.

[2]Applicable to the scaled-distance equation of Paragraph (d) (3) (i) of this Section

(ii) A seismographic record shall be provided for each blast.

(3) Scaled-distance equation.

(i) The permittee may use the scaled-distance equation, $W = (D/Ds)^2$, to determine the allowable charge weight of explosives to be detonated in any 8-millisecond period, without seismic monitoring; where W = the maximum weight of explosives, in pounds; D = the distance, in feet from the blasting site to the nearest protected structure; and Ds = the scaled-distance factor, which may initially be approved by the division using the values for scaled-distance factor listed in Paragraph (d) (2) (i) of this section.

(ii) The development of a modified scale-distance factor may be authorized by the Division on receipt of a written request by the permittee, supported by seismographic records of blasting at the minesite. The modified scale-distance factor shall be determined such that the particle velocity of the predicted ground vibration will not exceed the prescribed maximum allowable peak particle velocity of Paragraph (d) (2) (i) of this Section, at a 95-percent confidence level.

(4) Blasting-level chart.

(i) The permittee may use the ground vibration limits in Figure 1 to determine the maximum allowable ground vibration.

(ii) If the Figure 1 limits are used, a seismographic record including both particle velocity and vibration-frequency levels shall be provided for each blast. The method for the analysis of the predominant frequency contained in the blasting records shall be approved by the Division before application of this alternative blasting criterion.

(5) The maximum allowable ground vibration shall be reduced by the Division below the limits otherwise provided by this Section, if determined necessary to provide damage protection.

(6) The Division may require the permit-tee to conduct seismic monitoring of any or all blasts and may specify the location at which the measurements are taken and the degree of detail necessary in the measurement.

(e) The maximum airblast and ground-vibration standards of Paragraphs (b) and (d) of this Section shall not apply at the following locations:

(1) At structures owned by the permittee and not leased to another person.

(2) At structures owned by the permittee and leased to another person, if a written waiver by the lessee is submitted to the Division before blasting.

4 VAC 25-130-817.68 Use of Explosives: Records of Blasting Operations

The permittee shall retain a record of all blasts for at least 3 years. Upon request, copies of these records shall be made available to the Division and to the public for inspection. Such records shall contain the following data:

(a) Name of the permittee conducting the blast;

(b) Location, date, and time of the blast;

(c) Name, signature, and certification number of the blaster conducting the blast;

(d) Identification, direction, and distance, in feet, from the nearest blast hole to the nearest dwelling, public building, school, church, community or institutional building outside the permit area, except those described in 480-03-19.816.67 (e);

(e) Weather conditions, including those which may cause possible adverse blasting effects;

(f) Type of material blasted;

(g) Sketches of the blast pattern including number of holes, burden spacing, decks, and delay pattern;

(h) Diameter and depth of holes;

(i) Types of explosives used;

(j) Total weight of explosives used per hole;

(k) The maximum weight of explosives detonated in an 8-millisecond period;

(l) Initiation system;

(m) Type and length of stemming;

(n) Mats or other protections used;

(o) Seismographic and airblast records, if required, which shall include;

(1) Type of instrument, sensitivity, and calibration signal or certification of annual calibration;

(2) Exact location of instrument and the date, time, and distance from the blast;

(3) Name of the person and firm taking the reading;

(4) Name of the person and firm analyzing the seismographic record; and

(5) The vibration and/or airblast level recorded.

(p) Reasons and conditions for each unscheduled blast.

4 VAC 25-130-850- -TRAINING, EXAMINATIONS, AND CERTIFICATION OF BLASTERS

4 VAC 25-130-850.1 Scope

This part establishes the procedures for training, examination, and certification of persons engaged in or directly responsible for the use of explosives in surface coal mining operations.

A person who desires to become a certified blaster and receives a Division of Mined Land Reclamation (DMLR) endorsement certification must receive training that is approved by DMLR.

The Office of Surface Mining (OSM) requires this training that is regulated and approved by DMLR.

4 VAC 25-130-850.5 Definition

As used in this Part, Blaster means a person directly responsible for the use of explosives in surface coal mining operation who is certified under this Part.

4 VAC 25-130-850.12 Effective Date

Not later than twelve months following the approval by the Secretary of this Sub-chapter, all blasting operations shall be conducted under the direction of a certified blaster. Before that time, all such blasting operations shall be conducted by competent, experienced persons who understand the hazards involved, who are certified by the Division of Mines.

4 VAC 25-130-850.13 Training

(a) Persons seeking to become certified as blasters may receive training by contacting the DM office in Big Stone Gap. The training includes, but is not limited to, the technical aspects of blasting operations and State and Federal laws governing the storage, transportation, and use of explosives; and

(b) Persons who are not certified and who are assigned to a blasting crew or assist in the use of explosives shall receive direction and on-the-job training from a blaster.

(c) The DM course shall provide training and discuss practical applications of:

(1) Explosives, including:
(i) Selection of the type of explosive to be used:

(ii) Determination of the properties of explosives which will produce desired results at an acceptable level of risk; and
(iii) Handling, transportation and storage;

(2) Blasting designs, including:
(i) Geologic and topographic considerations;
(ii) Design of a blast hole, with critical dimensions;
(iii) Pattern design, field layout, and timing of blast holes; and
(iv) Field applications;

(3) Loading blast holes, including priming and boostering;

(4) Initiation systems and blasting machines;

(5) Blasting vibrations, airblasts and flyrock, including:
(i) Monitoring techniques, and
(ii) Methods to control adverse affects;

(6) Secondary blasting applications;

(7) Current Federal and State rules applicable to the use of explosives;

(8) Blast records;

(9) Schedules;

(10) Preblasting surveys, including
(i) Availability
(ii) Coverage, and
(iii) Use of in-blast designs;

(11) Blast plan requirements;

(12) Certification and training;

(13) Signs, warning signals, and site control;

(14) Unpredictable hazards, including:
(i) Lightning,
(ii) Stray current,
(iii) Radio waves, and
(iv) Misfires.

4 VAC 25-130-850.14 Examination

(a) The Division shall insure that candidates for blaster certification are examined by reviewing and verifying:

(1) The person passed the DM written examination covering blasting practices, transportation and storage of explosives, DM rules and regulations, and blasting controls; and

(2) The person has also passed the Division's Blaster's Coal Surface Mining Endorsement Test covering Part 4 VAC 25-130-850, 4 VAC 25-130-816.61 through 4 VAC 25-130-816.68 and 4 VAC 25-130-817.61 through 4 VAC 25-130-817.68; and

(3) The person must file an application and furnish proof of experience to the DM's Board of Mine Examiners. The minimum experience shall be at least one year of practical blasting field experience.

(b) Applicants for blasters certification shall be examined by both the Division and DM at a minimum, in the topics set forth in 4 VAC 25-130-850.13 (c).

4 VAC 25-130-850.15 Certification

(a) The Division shall issue the blaster's coal surface mining endorsement for a period of five years to those candidates examined and found to be competent and has met the requirements as described in 480-03-19.850.13 and 480-03-19.850.14.

(b) Suspension and revocation:

(1) The Division, when practicable, following written notice and opportunity for a hearing may, and upon finding of willful conduct by the DM Board of Mine Examiners, shall suspend or revoke the blaster's coal surface mining endorsement certification during the term of the certification or take other necessary action for any of the following reasons:
(i) Non-compliance with any blasting related orders issued by the Division or DM;
(ii) Unlawful use in the work place of, or current addiction to, alcohol, narcotics, or other dangerous drugs;
(iii) Violation of any provision of the State or Federal explosives laws or regulations;
(iv) Providing false information or a misrepresentation to obtain certification.

(2) If advance notice and opportunity for a hearing cannot be provided, an opportunity for a hearing shall be provided as soon as practical following the suspension, revocation, or other adverse action.

(c) Recertification. Any person certified as a blaster must be recertified every five years by:

(1) Presenting written proof that the individual has worked in a capacity which demonstrates the blaster's competency during two of the last three years immediately preceeding the expiration date; or

(2) Retaking the DMLR Division's endorsement exam and achieving the required scores on the exam. Anyone who fails to achieve the required score on the exam must take or retake the training prior to retaking both the Division's and DM's exam.

(d) Protection of certification. Certified blasters shall take every reasonable precaution to protect their certificates from loss, theft, or unauthorized duplication. Any such occurrence shall be reported immediately to the Division.

(e) Conditions:

(1) A blaster shall immediately exhibit upon request his or her certificate to any authorized representative of the Division, DM, or the Office of Surface Mining.

(2) Blaster's certification shall not be assigned or transferred.

(3) Blasters shall not delegate their responsibility to any individual who is not a certified blaster.

(f) Petitions for recertification.

An individual whose certification has been revoked may petition the DMLR for recertification. The DMLR shall not accept a petition for recertification any sooner than one year from the effective date of revocation. Such petitions shall show valid reasons why the Division should consider the request for recertification. The Division may require retesting prior to recertification.

(g) Appeals Procedures.

Appeals for review of certification including suspension and revocation decisions shall be made to the DMLR. Appeals not resolved by the DMLR may be heard pursuant to the provisions for administrative and judicial review under Chapter 19, Title 45.1 of the Code.

UNIT XV

NON-ELECTRIC EXPLOSIVE PRODUCTS SAFETY INFORMATION

- Always store, handle, transport and use all explosive products, including non-electric systems in accordance with manufacturer instructions.

- The use of explosive products by anyone who lacks adequate training, experience, and supervision may result in serious injury or death to those involved.

- Only properly trained, experienced surface blasters should use non-electric explosive products.

- Shock tube is a tough plastic tube with a thin coating of explosive on the inside.

- All mining personnel should be properly trained in the instructions, warnings and use of all explosive products including non-electric products.

- All mining personnel should be properly supervised by a surface blaster when handling, storing, transporting or using non-electric explosive products.

- Always protect non-electric detonators from unintended energy. Non-electric detonators must be protected against all of the following:

    1. The impact of a falling rock on a detonator;
    2. The impact of a drill stem on a misfired detonator;
    3. The impact of a track vehicle on a detonator;
    4. Open flame or fire;
    5. Lightning;
    6. Contact with electric wires.

- Always evacuate personnel to a safe location away from possible detonation or explosion when a lightning storm approaches.

- Always avoid situations where shock tube can become entangled or entwined in vehicles, machinery or equipment, and prematurely detonate.

- Always select and use all explosive products including non-electric systems appropriate for the conditions and intended use.

- Never cut or trim a shock tube.

- Never remove or crimp a detonator on a shock tube.

- Never allow water or moisture to enter shock tube. A misfire may occur if moisture or water is allowed to enter shock tube.

- Never cut or attempt to manufacture a desired length of detonator tubing because factor assembly of a capped unit is done with safeguards that you cannot duplicate.

- Never attempt to manufacture a delay or crimp a detonator. A premature or unplanned explosion may occur when detonators are not handled in accordance with manufacturer instructions.

- Never use any type of suspected damaged explosive products, including non-electric products.

- Always refer suspected damaged explosive products to the manufacturer for proper disposal.

- Never hold shock tube in your hand when detonating it. Shock tube that has been mishandled may rupture when detonated.

- Never mishandle, abuse or rupture shock tube or detonator tubing.

- Never pull, stretch, kink or put undue tension on shock tube or detonator tubing because any of these could cause damage resulting in a misfire.

- Never attempt to disassemble, crimp or uncrimp a detonator from its attached cord.

- Never attempt to disassemble a surface delay detonator from the connector block.

- Never attempt to initiate detonating cord with surface non-electric delay detonators, as a misfire could result.

- Always read, understand and follow instructions and warnings of explosive manufacturers.

- Always evacuate all personnel to a safe location and warn all others before explosives are detonated. All entrances to blast areas shall always be guarded to prevent unauthorized entry.

- Always rotate stocks of explosive products and use the oldest in your inventory first as age affects the integrity of detonators and other explosive products.

- Always transport, store and use all explosive products in accordance with all Federal, State and local laws.

- Always look for misfires and handle misfires as directed by State, Federal, and the Institute of Makers of Explosives.

- Always ensure security measures are taken to prevent theft of any explosive products.

- Always keep explosive products, including non-electric products, away from flame, heat, open lights, smoking, matches, stoves, radiators, etc.

- Heat may cause damage to explosive products resulting in misfires.

- Never load non-electric detonators or any other explosive products into a hot borehole or expose to temperatures above 150^o F.

- Never attach an initiating detonator or a starter to a lead-in or trunkline until everything is ready to fire the blast.

- Never use any explosive products for fireworks.

- Always select non-electric detonators with the proper length tube and absolutely never cut or attempt to manufacture a desired length of tube on a detonator.

- Always remember that delay elements are built into the assembly of detonators with the manufactured length of tube.

- Never abuse shock tube by driving over it. Shock tube exposed to damage or moisture may cause a misfire.

- Always report any suspected theft of any explosive products to the Bureau of Alcohol, Tobacco and Firearms (ATF), State and local police officials.

UNIT XVI

TITLE 30 – CODE OF FEDERAL REGULATIONS
EXPLOSIVES AND BLASTING – SUBPART N (77.1300)

TITLE 30 – CODE OF FEDERAL REGULATIONS
EXPLOSIVES AND BLASTING
SUBPART N (77.1300)

77.1300 Explosives and blasting.

(a) No explosives, blasting agent, detonator, or any other related blasting device or material shall be stored, transported, carried, handled, charge, fired, destroyed, or otherwise used, employed or disposed of by any person at a coal mine except in accordance with the provisions of §77.1301 through 77.1307, inclusive.

(b) The term "explosives" as used in this Subpart N includes blasting agents. The standards in this Subpart N in which the term "explosives" appears are applicable to blasting agents (as well as to other explosives) unless blasting agents are expressly excluded.

77.1301 Explosives; magazines.

(a) Detonators and explosives other than blasting agents shall be stored in magazines.
(b) Detonators shall not be stored in the same magazine with explosives.
(c) Magazines other than box type shall be:
  - (1) Located in accordance with the current American Table of Distances for storage of explosives;
  - (2) Detached structures located away from powerlines, fuel storage areas, and other possible sources of fire;
  - (3) Constructed substantially of noncombustible material or covered with fire-resistant material;
  - (4) Reasonably bullet resistant;
  - (5) Electrically bonded and grounded if constructed of metal;
  - (6) Made of nonsparking materials on the inside, including floors;
  - (7) Provided with adequate and effectively screened ventilation openings near the floor and ceiling;
  - (8) Kept locked securely when unattended;
  - (9) Posted with suitable danger signs so located that a bullet passing through the face of a sign will not strike the magazine;
  - (10) Used exclusively for storage of explosives or detonators and kept free of all extraneous materials;
  - (11) Kept clean and dry in the interior, and in good repair;
  - (12) Unheated, unless heated in a manner that does not create a fire or explosion hazard.

(d) Box-type magazines used to store explosives or detonators in work areas shall be constructed with only nonsparking material inside and equipped with covers or doors and shall be located out of the line of blasts.
(e) Secondary and box-type magazines shall be suitably labeled.
(f) Detonator-storage magazines shall be separated by at least 25 feet from explosive-storage magazines.
(g) Cases or boxes containing explosives shall not be stored in magazines on their ends or sides nor stacked more than 6 feet high.
(h) Ammonium nitrate-fuel oil blasting agents shall be physically separated from other explosives, safety fuse, or detonating cord stored in the same magazine and in such a manner that oil does not contaminate the other explosives, safety fuse or detonating cord.

77.1302 Vehicles used to transport explosives.

(a) Vehicles used to transport explosives, other than blasting agents, shall have substantially constructed bodies, not sparking metal exposed in the cargo space, and shall be equipped with suitable sides and tail gates; explosives shall not be piled higher than the side or end.

(b) Vehicles containing explosives or detonators shall be maintained in good condition and shall be operated at a safe speed and in accordance with all safe operating practices.

(c) Vehicles containing explosives or detonators shall be posted with proper warning signs.

(d) Other materials or supplies shall not be placed on or in the cargo space of a conveyance containing explosives, detonating cord or detonators, except for safety fuse and except for properly secured nonsparking equipment used expressly in the handling of such explosives, detonating cord or detonators.

(e) Explosives and detonators shall be transported in separate vehicles unless separated by 4 inches of hardwood or the equivalent.

(f) Explosives or detonators shall be transported promptly without undue delays in transit.

(g) Explosives or detonators shall be transported at times and over routes that expose a minimum number of persons.

(h) Only the necessary attendants shall ride on or in vehicles containing explosives or detonators.

(i) Vehicles shall be attended, whenever practical and possible, while loaded with explosives or detonators.

(j) When vehicles containing explosives or detonators are parked, the brakes shall be set, the motive power shut off, and the vehicles shall be blocked securely against rolling.

(k) Vehicles containing explosives or detonators shall not be taken to a repair garage or shop for any purpose.

77.1303 Explosives, handling and use.

(a) Persons who use or handle explosive or detonators shall be experienced men who understand the hazards involved; trainees shall do such work only under the supervision of and in the immediate presence of experienced men.

(b) Blasting operations shall be under the direct control of authorized persons.

(c) Substantial nonconductive closed containers shall be used to carry explosives, other than blasting agents to the blasting site.

(d) Damaged or deteriorated explosives or detonators shall be destroyed in a safe manner.

(e) Where electric blasting is to be performed, electric circuits to equipment in the immediate area to be blasted shall be deenergized before explosives or detonators are brought into the area; the power shall not be turned on again until after the shots are fired.

(f) Explosives shall be kept separated from detonators until charging is started.

(g) Areas in which charged holes are awaiting firing shall be guarded, or barricaded and posted, or flagged against unauthorized entry.

(h) Ample warning shall be given before blasts are fired. All persons shall be cleared and removed from the blasting area unless suitable blasting shelters are provided to protect men endangered by concussion or flyrock from the blasting.

(i) Lead wires and blasting lines shall not be strung across power conductors, pipelines, railroad tracks, or within 20 feet of bare powerlines. They shall be protected from sources of static or other electrical contact.

(j) For the protection of underground workers, special precautions shall be taken when blasting in close proximity to underground operations, and no blasting shall be done that would be hazardous to person working underground.

(k) Holes shall not be drilled where there is danger of intersecting a charged or misfired hole.

(l) Only wooden or other nonsparking implements shall be used to punch holes in an explosive cartridge.

(m) Tampering poles shall be blunt and squared at one end and made of wood, nonsparking material, or of special plastic acceptable to the Mine Safety and Health Administration.

(n) Delay connectors for firing detonating cord shall be treated and handled with the same safety precautions as blasting caps and electric detonators.

(o) Capped primers shall be made up at the time of charging and as close to the blasting site as conditions allow.

(p) A capped primer shall be prepared so that the detonator is contained securely and is completely embedded within the explosive cartridge.

(q) No tamping shall be done directly on a capped primer.

(r) Detonating cord shall not be used if it has been kinked, bent, or otherwise handled in such a manner that the train of detonation may be interrupted.

(s) Fuse shall not be used if it has been kinked, bent sharply, or handled roughly in such a manner that the train of deflagration may be interrupted.

(t) Blasting caps shall be crimped to a fuse only with implements designed for that specific purpose.

(u) When firing from 1 to 15 blasting holes with safety fuse ignited individually using hand-held lighters, the fuses shall be of such lengths to provide the minimum burning time specified in the following table for a particular size round:

Number of holes in a Round	Minimum burning time, minutes
2	2
2 to 5	2 2/3
6 to 10	3 1/3
11 to 15	5

In no case shall any 40-second-per-foot safety fuse less than 36 inches long or in any 30-second-per-foot safety fuse less than 48 inches long be used.

(v) The burning rate of the safety fuse in use at any time shall be measured, posted in conspicuous location, and brought to the attention of all men concerned with blasting.

(w) Electric detonators of different brands shall not be used in the same round.

(x) Adequate priming shall be employed to guard against misfires, increased toxic fumes, and poor performance.

(y) Except when being tested with a blasting galvanometer:

(1) Electric detonators shall be kept shunted until they are being connected to the blasting line or wired into a blasting round.

(2) Wired rounds shall be kept shunted until they are being connected to the blasting line.

(3) Blasting lines shall be kept shunted until immediately before blasting.

(z) Completely wired rounds shall be tested with a blasting galvanometer before connections are made to the blasting line.

(aa) Permanent blasting lines shall be properly supported, insulated, and kept in good repair.

(bb) At least a 5-foot airgap shall be provided between the blasting circuit and the power circuit.

(cc) When instantaneous blasting is performed, the double-trunkline or loop system shall be used in detonating-cord blasting.

(dd) When instantaneous blasting is performed, trunklines, in multiple-row blasts, shall make one or more complete loops, with crossties between loops at intervals of not over 200 feet.

(ee) All detonating cord knots shall be tight and all connections shall be kept at right angles to the trunklines.

(ff) Power sources shall be suitable for the number of electrical detonators to be fired and for the type of circuits used.

(gg) Electric circuits from the blasting switches to the blast area shall not be grounded.

(hh) Safety switches and blasting switches shall be labeled, encased in boxed, and arranged so that the covers of the boxes cannot be closed with the switches in the through-circuit or firing position.

(ii) Blasting switches shall be locked in the open position, except when closed to fire the blast. Lead wires shall not be connected to the blasting switch until the shot is ready to be fired.

(jj) The key or other control to an electrical firing device shall be entrusted only to the person designated to fire the round or rounds.

(kk) If branch circuits are used when blasts are fired from power circuits, safety switches located at safe distances from the blast areas shall be provided in addition to the main blasting switch.

(ll) Misfires shall be reported to the proper supervisor and shall be disposed of safely before any other work is performed in that blasting area.

(mm) When safety fuse has been used, men shall not return to misfired holes for at least 30 minutes.

(nn) When electrical blasting caps have been used, men shall not return to misfired holes for at least 15 minutes.

(oo) If explosives are suspected of burning in a hole, all persons in the endangered area shall move to a safe location and no one should return to the hole until the danger has passed but in no case within 1 hour.

(pp) Blasted areas shall be examined for undetonated explosives after each blast and undetonated explosives found shall be disposed of safely.

(qq) Blasted areas shall not be reentered by any person after firing until such time as concentrations of smoke, dust, or fumes have been reduced to safe limits.

(rr) In secondary blasting, if more than one shot is to be fired at one time, blasting shall be done electrically or with detonating cord.

(ss) Unused explosives and detonators shall be moved to a safe location as soon as charging operations are completed.

(tt) When electric detonators are used, charging shall be stopped immediately when the presence of static electricity or stray currents is detected; the condition shall be remedied before charging is resumed.

(uu) When electric detonators are used, charging shall be suspended and men withdrawn to a safe location upon the approach of an electrical storm.

77.1304 Blasting agents; special provisions.

(a) Sensitized ammonium nitrate blasting agents, and the components thereof prior to mixing, shall be mixed and stored in accordance with the recommendations in Bureau of Mines Information Circular 8179, "Safety Recommendations for Sensitized Ammonium Nitrate Blasting Agents, : or subsequent revisions.

(b) Where pneumatic loading is employed, before any type of blasting operation using blasting agents is put into effect, an evaluation of the potential hazard of static electricity shall be made. Adequate steps, including the grounding and bonding of the conductive parts of pneumatic loading equipment, shall be taken to eliminate the hazard of static electricity before blasting agent use is commenced.

(c) Pneumatic loading equipment shall not be grounded to waterlines, airlines, rails, or the permanent electrical grounding systems.

(d) Hoses used in connection with pneumatic loading machines shall be of the semiconductive type, having a total resistance low enough to permit the dissipation of static electricity and high enough to limit the flow of stray electric currents to a safe level. Wire-countered hose shall not be used because of the potential hazard for stray electric currents.

UNIT XVII
SURFACE BLASTING RECORD
Practice Exercise

Exam Instructions: You are required to read the blasting record information provided below and (1) complete the surface blasting record (2) complete the firing sequence record (3) compute the maximum weight of explosives within any 8 MS period and insert in blank space provided below.

You are a certified surface blaster, certification no. 22211, employed by Long Coal Company, company/permittee. The blast location is in grid A-1. The date is December 1, 2002 and time of the blast will be 10:00 A.M. The type of material being blasted is the shale. A total amount of 5280 lbs. of ANFO will be used and one-pound primers will be used in each hole to initiate the charge. The total number of holes will be 24; the burden is 12 feet and spacing is 18 feet. The diameter of the holes is 6 and ½ inches and depth of the holes is 25 feet. Drill cuttings will be used as stemming for a depth of 8 feet. A nonelectric system will be utilized for initiation. The delay types will be 17 ms, 42 ms, and 400 ms. The total weight of explosives per hole will be 220 lbs. the maximum weight of explosives within any 8 ms period will be _________ lbs. Mats or other protective devices will not be used. The nearest protected structure is the Big Ridge Baptist Church that is located southeast (SE) approximately 2200 feet. The weather is cloudy and raining. The temperature is approximately 39^0 F and wind is blowing from the southeast (SE) at approximately 10 mph. The blast will be monitored with a Vibratech seismograph. Sam Smith, employed by Advanced Monitoring, Inc., will operate the seismograph. Bill Jones, employed by Vibratech Monitoring, Inc., will analyze the record. The seismograph will be located at the Big Ridge Baptist Church at a distance of 2200 feet from the blast. The ground vibration level was .50 inches per second (IPS) and the air blast level was 110dB.

Name: ________________________________ Exam Date: ________________________

SURFACE BLASTING RECORD – Practice Exercise

Company/Permittee: ____

Date: ______________________ Time of Blast __________________ A.M. _____ P.M. _____

Location of Blast ____

Type of Material: Limestone _____ Sandstone _____ Slate _____ Shale _____ Other _____

Amount and Type of Explosive Used: ____

Total No. of Holes _______________ Burden ______________ Spacing ________________

Depth of Holes ___________________ Diameter of Holes _____________________________

Type of Stemming ____________________ Depth of Stemming ________________________

Method of Initiation: Non Electric ____________________ Electric _____________________

Delay Types ____________________ Type of Circuit (If Electric) _______________________

Total Weight of Explosives Per Hole: ____

Maximum Weight of Explosives Within 8 MS Period: ______________________________

Mat or Other Protection Used: ____

Nearest Protected Structure (Dwelling, School, Church, Commercial Building, Etc.)

Name of Structure and/or Type: ____

Distance: _____________________________ Direction ___________________________

Weather Conditions: Dry ___ Rain ___ Snow ___ Clear ___ Cloudy ___ Foggy ____

Temperature: _________ Wind Direction: __________ Approx. Wind Velocity: ______________

Seismograph Records Where Required

Type of Instrument: ____

Name of Person and Firm Taking Reading: _____________________________________

Name of Person and firm Analyzing Record: ___________________________________

Location of Seismograph: ____

Distance of Seismograph from Blast: ____

Vibration Level: ______________________ Air Blast Level: __________________________

Unscheduled Blasts: Reasons/Conditions ____

____

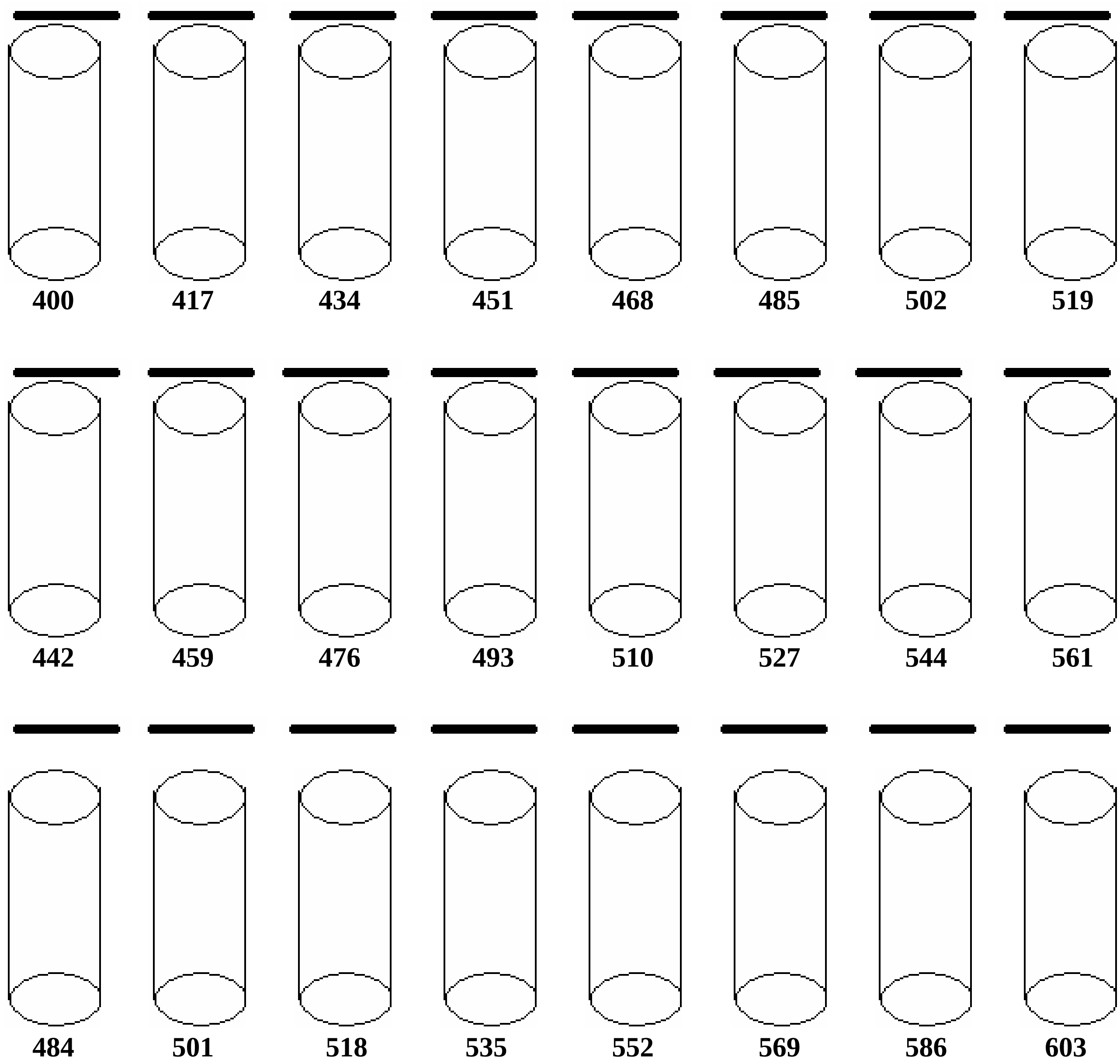
Name of Blaster: ________________________ Blaster Certification Number: _______________

Name: ______________________________ Exam Date: ______________________________

SURFACE BLASTING RECORD
SHOT DIAGRAM-Practice Exercise

3 Rows/8 Holes Per Row
17ms Between Holes
42 ms Between Rows
400 ms Down-Hole Delays

Based on the delays between the holes and delays between the rows, you are required to identify the correct firing sequence by placing appropriate numbers in the space provided above each borehole. Ex: 1, 2, 3, 4, 5 etc.



SURFACE BLASTING RECORD
Practice Exercise – Answer Key

Exam Instructions: You are required to read the blasting record information provided below and (1) complete the surface blasting record (2) complete the firing sequence record (3) compute the maximum weight of explosives within any 8 MS period and insert in blank space provided below.

2 Points Discount For Each Incorrect Answer

You are a certified surface blaster, certification no. 22211, employed by Long Coal Company, company/permittee. The blast location is in grid A-1. The date is December 1, 2002 and time of the blast will be 10:00 A.M. The type of material being blasted is shale. A total amount of 5280 lbs. of ANFO will be used and one-pound primers will be used in each hole to initiate charge. The total number of holes will be 24; the burden is 12 feet and spacing is 18 feet. The diameter of the holes is 6 and ½ inches and depth of the holes is 25 feet. Drill cuttings will be used as stemming for a depth of 8 feet. A nonelectric system will be utilized for initiation. The delay types will be 17 ms, 42 ms, and 400 ms. The total weight of explosives per hole will be 220 lbs. the maximum weight of explosives within any 8 ms period will be **400** lbs. Mats or other protective devices will not be used. The nearest protected structure is the Big Ridge Baptist Church that is located southeast (SE) approximately 2200 feet. The weather is cloudy and raining. The temperature is approximately 39^{o} F and wind is blowing from the southeast (SE) at approximately 10 mph. The blast will be monitored with a Vibratech seismograph. Sam Smith, employed by Advanced Monitoring, Inc., will operate the seismograph. Bill Jones, employed by Vibratech Monitoring, Inc., will analyze the record. The seismograph will be located at the Big Ridge Baptist Church at a distance of 2200 feet from the blast. The ground vibration level was .50 inches per second (IPS) and the air blast level was 110dB.

Name: ____________________ Exam Date: ____________________

SURFACE BLASTING RECORD – Practice Exercise Answer Key

Company/Permittee: **Long Coal Company**

Date: **12-1-02** Time of Blast **10:00** A.M. √ P.M. ____

Location of Blast **Grid A-1**

Type of Material: Limestone ____ Sandstone ____ Slate ____ Shale √ Other ____

Amount and Type of Explosive Used: **5280 lbs. ANFO and 24 one lb. primers**

Total No. of Holes **24** Burden **12 Feet** Spacing **18 Feet**

Depth of Holes **25 Feet** Diameter of Holes **6 ½ Inches**

Type of Stemming **Drill Cuttings** Depth of Stemming **8 Feet**

Method of Initiation: Non Electric √ Electric ____

Delay Types **17 MS, 42 MS, 400 MS** Type of Circuit (If Electric) **N/A**

Total Weight of Explosives Per Hole: **220 lbs.**

Maximum Weight of Explosives Within 8 MS Period: **440lbs**

Mat or Other Protection Used: **None**

Nearest Protected Structure (Dwelling, School, Church, Commercial Building, Etc.)

Name of Structure and/or Type: **Big Ridge Baptist Church**

Distance: **2200 Feet** Direction **SE**

Weather Conditions: Dry ____ Rain √ Snow ____ Clear ____ Cloudy √ Foggy ____

Temperature: **39^o** Wind Direction: **SE** Approx. Wind Velocity: **10mph**

Seismograph Records Where Required

Type of Instrument: **Vibratech**

Name of Person and Firm Taking Reading: **Sam Smith – Advanced Monitoring, Inc.**

Name of Person and firm Analyzing Record: **Bill Jones – Vibratech Monitoring, Inc.**

Location of Seismograph: **Big Ridge Baptist Church**

Distance of Seismograph from Blast: **2200 Feet**

Vibration Level: **.50 IPS** Air Blast Level: **110 dB**

Unscheduled Blasts: Reasons/Conditions ____________________

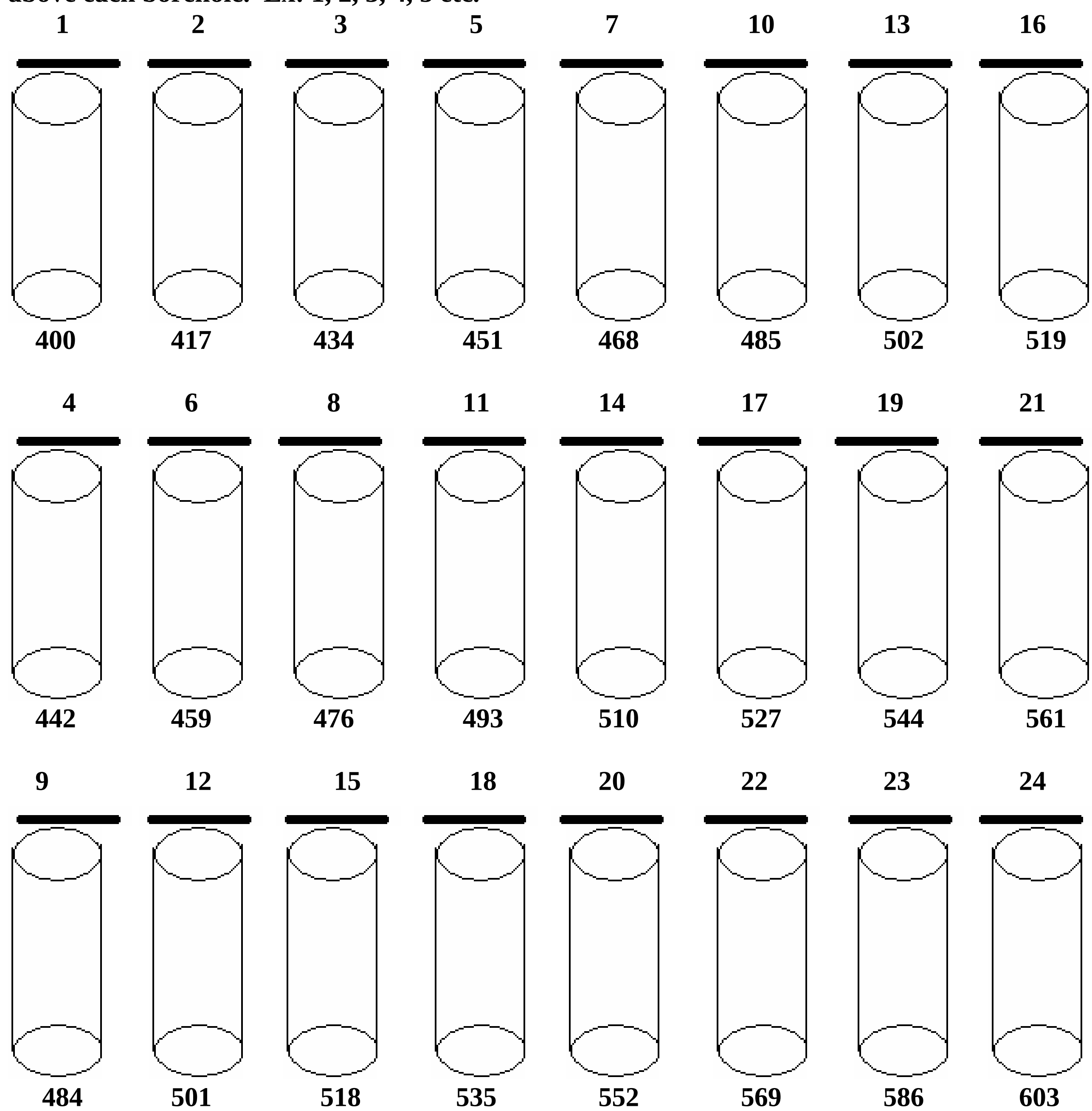
Name of Blaster: **(Student Name)** Blaster Certification Number: **22211**

Name: ______________________________ Exam Date: ______________________________

SURFACE BLASTING RECORD
SHOT DIAGRAM-Practice Exercise

3 Rows/8 Holes Per Row
17ms Between Holes
42 ms Between Rows
400 ms Down-Hole Delays

Based on the delays between the holes and delays between the rows, you are required to identify the correct firing sequence by placing appropriate numbers in the space provided above each borehole. Ex: 1, 2, 3, 4, 5 etc.



UNIT XVIII

XVIII REFERENCES

I. COAL MINE SAFETY LAWS OF VIRGINIA

II. 30 CFR – CODE OF FEDERAL REGULATIONS

III. DUPONT BLASTING MANUAL

IV. ATLAS BLASTING MANUAL

V. BUREAU OF ALCOHOL, TOBACCO AND FIREARM (ATF) – EXPLOSIVES LAWS AND REGULATIONS

VI. BUREAU OF MINES – EXPLOSIVES AND BLASTING PROCEDURES MANUAL