Chapter 10
GENERAL BLASTING

BLASTING MATS

Blasting mats are heavy mats of steel rope, rubber, or heavy rope. The mats are placed over the loaded holes just before firing to contain the blast and help prevent flyrock. The size of the mats depend on the needs of the blaster. If the blasting mats are to cover light charges of explosives, they may be spread directly over the boreholes. If heavier charges are used, railroad ties or logs are commonly put down first and then the mat is placed over them.

Steel mats are very heavy and are commonly used on small jobs, or jobs where there is special handling equipment. If steel mats are used, care should be taken to keep them from touching the connections of the blasting circuit. Such contact may cause a short or break in the blasting circuit. Matting and the use of backfill is required by law where there is a chance of flyrock.

An unconnected layer of old tires or plywood sheets or mattresses is NOT a mat!

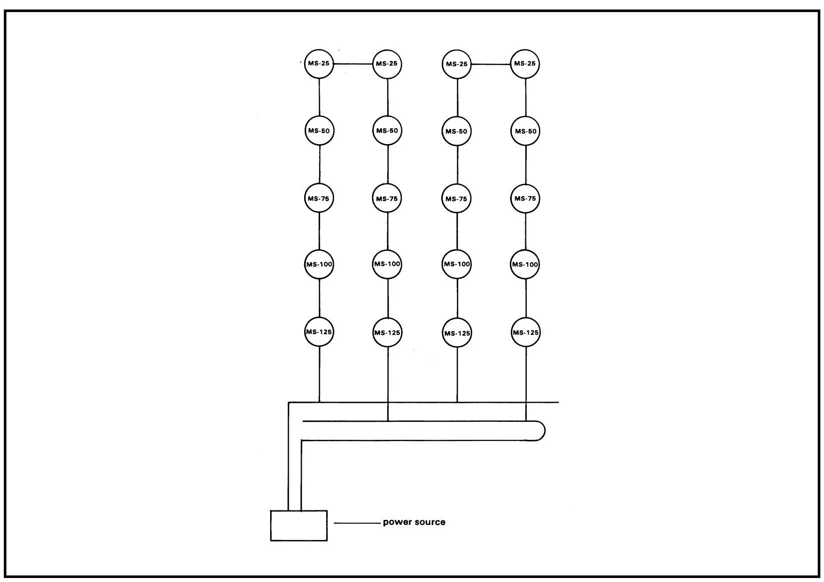
SEQUENTIAL BLASTING

Small, primary blasts tend to slow production in the surface mining industry. As a result, a demand exists for a technique to enable the blaster in the field to increase shot size while staying within the scaled distance limits. Previously discussed were the various types of delay systems and delay electric blasting caps, one of the more commonly used devices for achieving better fragmentation. Unlike fragmentation achieved by simultaneously detonating charges, delay systems and caps enable an increase in the size of primary shots by taking advantage of the many delay periods available on the market today.

One disadvantage for the blaster who finds large primary shots a desirable and necessary part of a project is that delay periods in caps are limited. (Before deciding upon the size of each blast, one should consult an explosive dealer regarding which periods are available.) And, depending upon the area in which the blasting is taking place, the larger shots could cause excessive noise and ground vibration, resulting in complaints from residents. Needless to say, a limited number of delay periods are available, and a congested blasting area can prevent enlarged shots.

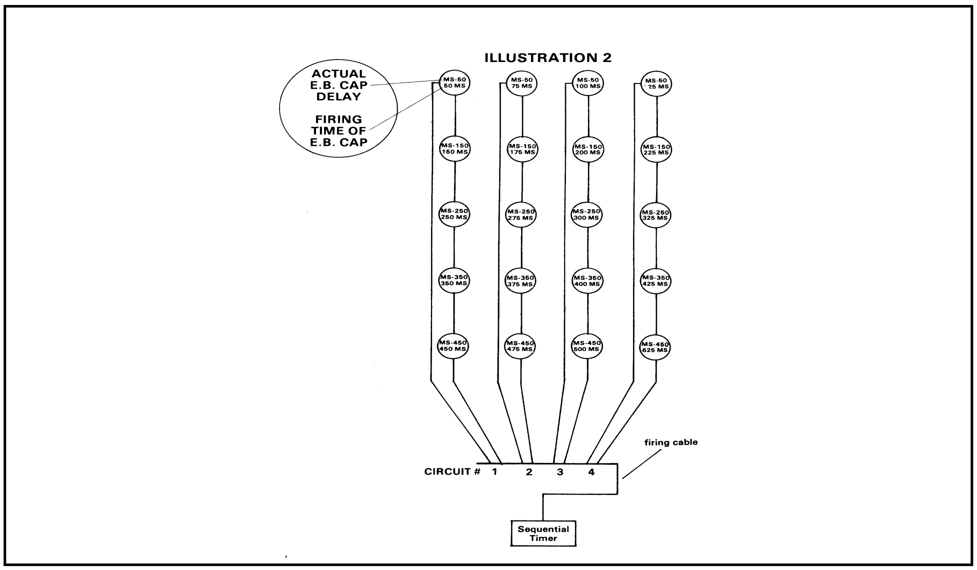
An alternative in electric blasting is the sequential blasting machine. Unlike the more conventional type capacitor discharge machines, the sequential machine delivers electronically timed bursts of energy to a number of conductors, or lead wires. By making careful selection of delay periods, the amount of explosive pounds per delay detonating may be increased to a significant degree. Also, it is possible to increase the size of a shot by using one of these instruments.

Figure 10-1 illustrates a typical primary blast consisting of two series wired in a parallel circuit. A limited number of delay periods may force the blaster to arrange his delays as in this diagram. When detonated, this arrangement causes each row to move toward the open face simultaneously. Any attempt to arrange this shot in a "V" cut pattern could force the blaster to overuse the last delay period in the rear of the shot. If the explosive pounds per delay interval limit is achieved, then this shot reaches maximum size. And, in this particular example, when using a capacitance discharge blasting machine (which will deliver one burst of electrical energy upon command), the delay periods used will determine the delaying sequence of each charge.



(Figure 10-1) Sequential blasting machine operation.

By using the sequential blasting machine shown in Figure 10-2, one may detect a slight difference. Four series of caps are connected to the firing cable of the machine which delivers bursts of energy at 25 milliseconds intervals. Since the delay period separates each row by 100 milliseconds, the current passing through the firing cable at 25 millisecond intervals allows each hole to detonate individually. The amount of explosive pounds detonating per delay interval is reduced to a fourth of the amount detonating in the Figure 10-1. The shot size may be increased providing there is sufficient distance between the nearest home and the blasting site.



(Figure 10-2) Sequential blasting machine operation.

The sequential blasting machine is not, however, without certain limiting factors. The limitations exist not only within the machines, but also in the delay periods used. As higher delay periods are approached, a slight margin of error is encountered in the delay mechanism. A margin setting of 10 milliseconds could cause charges to detonate at time sequences of less than eight milliseconds apart if the delay period detonates the charges prematurely. (The margin of error in some delay caps can cause an overlapping of detonation of charges which will result in charges detonating at less than eight milliseconds apart.)

DESTRUCTION OF EXPLOSIVES (NON-DETERIORATED PRODUCT)

MISFIRES

If a misfire occurs, the blaster-in-charge must provide safeguards to exclude employees from the danger zone. All work shall cease except that which is necessary to remove the hazard of the misfire. Only those employees needed to do the work shall remain in the danger zone.

If there is a reason to believe a charge is burning in a hole, the blaster must evacuate the danger area and post and guard it for 12 hours. With electric blasting caps or nonelectric detonation systems, wait at least 30 minutes. If the misfire is considered electrical, recheck the wiring before returning to the danger area. Next, disconnect the lead wires, and check again with the galvanometer for a load exceeding the firing capacity of the blasting machine, and for broken or ground circuits.

If possible, another detonator shall be inserted into the shot and fired again. If a misfire occurs in solid material and has been stemmed with water, another primer shall be prepared, placed on top of the first charge, and fired again.

If a misfire takes place in solid material and has been stemmed or tamped with dirt, or clay, the packing or stemming material shall be blown out with compressed air from a semi-conductive hose or washed out with water. When enough of the stemming material has been removed to expose explosives in the hole, another primer shall be prepared, placed, and the blast refired.

Note - No drilling, digging or picking shall be permitted.

After the blast, a careful search for undetonated explosives is necessary. Explosives recovered from blasting misfires shall be disposed of or placed in a separate magazine until competent personnel determine a method of disposal. Caps recovered from blasting misfires shall not be reused and shall be disposed of.

Most misfires are due to some problem with the initiation system such as failure to make a connection, a broken lead wire, or simply not understanding the initiation system. Other causes of misfires are inadequate priming and malfunctioning explosives due to improper storage.

Detection of a misfire is no problem if none of the holes detonate. However, if a few holes or portions of a single hole fail to detonate, detection of the misfire can be very difficult and dangerous. In these cases, visual inspection of the muck pile for undetonated explosives and boulders, or other irregularities that suggest possible misfires, is the most reliable detection method.

Disposal of detected misfires is accomplished by removing the explosives with water or air flushing, repriming, and reshooting, or by detonating a nearby charge. Be aware, however, that detonating a nearby charge can be very dangerous and is not recommended.

The best way to avoid misfire accidents and costs is to eliminate their causes. This can be achieved by knowing the characteristics of the explosives, delays, and initiation system; proper blasting design; taking care in loading the shot and hooking up the initiation system; and by maintaining good housekeeping practices at the blasting site.

DISPOSING OF DETERIORATED OR DAMAGED EXPLOSIVES

General

Explosives and detonators are specifically manufactured to do only one thing well—EXPLODE. To accomplish that, they are purposely made with chemicals that are inherently highly reactive, and unpredictably in such products equates to danger, which may be extreme. The fundamental difference between excess explosives and deteriorated explosives is that deterioration quickly renders the product unreliable *and unpredictable*. Product stability and sensitivity will be changed, and there is no reliable way to predict the nature and extent of that change, particularly given the complex interaction of factors affecting it.

For this reason, both the Environmental Protection Agency and the National Park Service treat the handling and disposal of deteriorated explosives and detonators as a Hazardous Waste activity, NOT a blasting activity. Both agencies require that anyone physically handling deteriorated products be specifically licensed for that activity, and that the license be acceptable to EPA. To obtain a license requires a minimum level of specialized training in explosives chemistry, deterioration effects and risk assessment, and handling and disposal techniques, along with a minimum level of supervised disposal experience.

To repeat: The handling and disposal of deteriorated explosives and detonators is NOT a blasting activity, and a standard blaster's license in no way qualifies any person to safely engage in that activity. Even a slight misjudgment of product stability and sensitivity could be fatal. See *NPS-65* for more details on training and experience requirements for persons licensed as explosives disposers.

If burning is necessary, keep in mind that burning some explosives can cause them to detonate. As a result, they should be treated as if they will detonate. Proceed with burning as follows:

a. Do not burn explosives in deep piles. Spread sticks about one inch apart.
b. Empty boxes, paper and fiber packing materials that have previously contained high explosives shall not be used again for any purpose. Make sure they are empty, then destroy by burning at an approved location.
c. Keep disposal area clear of personnel until all debris is cooled.
d. Do not place explosive on hot ground.
e. Do not stir or add explosives after burning is started.
f. Exercise care to prevent disposal crew from inhaling fumes from burning explosives.
g. Maintain proper quantity distance from explosives.

Dynamite

Do not attempt to move any deteriorated nitroglycerin based product that cannot be destroyed in place by detonating. Leave a guard in the area and call your state police bomb squad.

Other Explosives

Some explosives, particularly newer types, may require disposal techniques other than detonating or burning. For example, a two-component explosive (fertilizer) usually can be deactivated by diluting the mixed explosive with an ample supply of water and spreading it on mineral soil adjacent to a road or trail, or a borrow pit area.

Consult the explosives manufacturer for specific disposal practices and recommendations. Explosives manufacturers have agreed to take explosives that are damaged, unusable, or deteriorated.

Detonators

Destroy all delay or instant electric blasting caps that have deteriorated from age or improper storage to an extent that they are unfit for use. Such caps may be very dangerous to handle. They should not be disturbed until an experienced blaster certified for disposal or a technical representative of the manufacturer has an opportunity to check them.

Detonators that have deteriorated or have been proven defective by a blaster’s ohmmeter should be destroyed with an explosive or returned to the manufacturer. Corrosion is one sign of deterioration.

Do not throw detonators into wells or any body of water such as water-filled abandoned quarries.

If required, destroy detonators as follows:

a. Separate the detonator from the shunted wire by about one foot. Do not remove the shunt. Keep the remaining wire coiled as originally packed. Prepare no more than 50 detonators and place in a hole where they will be confined.
b. Make up an explosive charge that will cover the detonators and prime the charge with a good detonator or detonating cord.
c. After shooting thoroughly, examine the ground around the shot to be sure no unexploded detonators remain.
d. Do not use the same area for successive shots unless the entire area feels cool.

DETONATING CORD

Detonating cord can be disposed of in the same manner as detonators by confinement in a hole, placing a charge on top of the hole, and detonating.

GROUND VIBRATION AND AIR BLAST

A. Ground vibrations and air blast damage may become a serious problem to any blasting operation that must be carried out around populated areas, facilities, or structures. The Bureau of Mines has conducted many studies on the subject of ground vibrations and air blast as it relates to surface mining.

These studies have determined that particle velocity is the best criterion for predicting the probability of structural damage due to ground-borne vibrations. If the limits of most loading are followed to eliminate damaging ground vibrations, then the air blast hazard is usually compensated for automatically.

B. To maintain vibration within acceptable limits, studies by the Bureau of Mines have determined that a peak particle velocity of two inches per second adjacent to a structure will result in the probability of little vibration damage. The further limiting of peak velocity to 0.4 inches per second should minimize complaints from adjacent property owners. The Surface Mining Control and Reclamation Act (P.L. 95-87) limits the maximum particle velocity to one inch per second, and this is the standard that shall be followed in NPS blasting. In the absence of instrumentation, use a scaled distance of 60 times the square root of the weight of the charge as the minimum safe blasting distance.

C. Usually the distance from the blast area to the nearest structure is fixed. To determine the amount of explosives per delay period of eight milliseconds or greater that is permissible, use the following procedure:

$$D/\sqrt{W} > 60$$

That is, the distance in feet (D) from the blast to the point of concern divided by the square root of the charge in pounds per delay (W), should equal 60 or more.

D. As an example of use:

1. 25 lb/delay of explosives are to be used in a shot. A house is 350 feet from the blast site.

$$\frac{350}{\sqrt{25}} > 60 \quad \text{or}$$

$$\frac{350}{5} = 70 > 60$$

Because 70 is greater than 60, the loading in relation to the house is within the safe limit.

E. The nearest house is 2000 feet away. How much explosive per delay can be used and still be safe?

$$D\sqrt{W} = 60 \quad \text{or}$$
$$\sqrt{W} = D/60$$

$$\sqrt{W} = 2{,}000/60$$
$$\sqrt{W} = 33.33$$

$$\text{Then } W^2 = 1{,}110 \text{ lbs}$$

1110 pounds per delay can be used and still be safe.

F. 36 pounds per delay is used in a shot. How far must the nearest house be to stay within the safe limits?

$$D\sqrt{W} = 60$$
$$D = 60\sqrt{W}$$

$$D = 60 \times \sqrt{36}$$
$$D = 360$$

The nearest house must not be nearer than 360 feet and still be safe.

G. A shot design uses 10 holes of 40 pounds each. The nearest house is 720 feet away. How many holes can be shot safely per delay?

$$D\sqrt{W} = 60$$
$$\sqrt{W} = D/60$$
$$\sqrt{W} = 720/60$$
$$\sqrt{W} = 12$$
$$W = 144$$

Use up to 144 pounds per delay. Because each hole contains 40 pounds each, no more than three holes can be shot per delay. The minimum number of delay periods is four.

H. In areas where complaints are likely, it may be wise to increase the scaled distance to 100. The basic equation in this case would be:

$$D\sqrt{W} = 100$$

I. The following table gives allowable weights of explosives per delay at various actual distances for scaled distances of 60 and 100:

Actual distance	Safe weight of explosives per delay at SD 60	Safe weight of explosives per delay at SD 100
10	0.03	0.01
25	0.17	0.06
50	0.69	0.25
100	2.78	1.00
250	17.40	6.25
500	69.40	25.00
1,000	277.80	100.00

Delay must be equal to or greater than 8 milliseconds.

J. This is a very limited discussion of ground vibration and air blast. For large blasts or continuing projects in close proximity to sensitive areas, see *Bureau of Mines Bulletin 656* or consult the regional blaster examiner for direction.

K. Air blast does not contribute to the damage problem in most blasting operations. A safe blasting limit, .007 psi over pressure air blast, is recommended. This will equal to 128 dB on the linear peak scale and is the maximum allowed by public law.

L. Except in extreme cases, lack of adequate stemming (surface shots), the control of blasting procedures to limit ground vibration levels below l.0 inches per second, automatically limits overpressure to safe levels. In sensitive areas, it may be necessary to eliminate the use of detonating cord on the surface to minimize air blast.

M. Precautionary measures that will help in eliminating complaints and damages from air blast:

1. Use adequate burden and stemming (confinement).

2. Blast when wind is favorable (away from structures and populated areas).

3. Avoid blasting during temperature inversions.

4. Avoid or cover surface detonating cord.

5. Blast during period of high ambient noise (noon).

N. Other types of surface blasting may require the use of seismic instrumentation, especially where structures are within one mile of the blast site.

BLASTING VIBRATION AND AIR BLAST

Blasting vibration and air blast are two conditions that can cause people living in the area of a blast to register complaints. Such complaints can be communicated to the operator or to governmental and regulatory agencies.

Severe vibrations and air blast can and *do* cause structural damage to nearby buildings. These conditions must be controlled by the blaster. Less severe vibrations and air blast may not cause damage, yet they still disturb residents of the area. The response to lower level vibrations can range from no complaints at all to annoyance complaints, and even claims for damage.

Obviously, it would benefit the blaster to control blast vibrations to eliminate damage to structures and minimize complaints. Adequate control of vibration and air blast (noise) can usually be accomplished by proper blast design and planning. Such planning and design can usually be undertaken by the blaster. However, if the situation is serious and difficult to deal with, the blaster should consult an expert on both vibration control and blasting.

When an explosive detonates, a large amount of energy is rapidly released by the means through a chemical reaction. The shock and pressure from the gas react against the area around the explosion—the ground and the air.

If the pressure wave travels through the atmosphere, it is called *air blast* or *air overpressure*. If the wave travels along the surface of the earth, it is called *blast vibration*. Air blast can be felt and may be thought to be ground vibration because it is low frequency and cannot be heard. This low frequency sound is called *concussion*. Movement of rock can also cause movement of the air, which can be felt as a concussion. Consequently, a concussion wave may result without any noise.

Normally, both vibration and air blast are produced by the detonation of an explosive. However, the effect of one may be stronger than the other, depending on how the explosive is confined at the instant of detonation. An explosion in a borehole will produce a pressure wave in the earth surrounding the borehole. As the pressure wave propagates, or travels away from the borehole, it stabilizes into what is called a *seismic wave*. Two modes of seismic wave propagation have been identified. One is a body wave propagation, through the earth, and the other is a surface wave that propagates at ground level. Usually, a surface wave is produced when a body wave travels to the surface and is reflected back to the earth. The disruption of the surface by the reflection of the body wave creates the surface wave. The movement of these waves is similar to the ripples of a pool into which a rock is thrown.

The earth consists of many minute particles of rock that are cemented together. There is a small amount of give, or elasticity, in this cement. Vibration is actually the displacement or movement of these particles. The particles are displaced a fraction of an inch by the pressure wave. Then, the elastic nature of the cement takes over and the particles begin oscillating. As the oscillations cease, the particles return to their original position. Such oscillations are measured and recorded to determine the magnitude of the blasting vibration.

Blasting seismographs are used to measure and record the vibration. Three terms are utilized in this process. They are based on elastic wave theory and are related to the movement of the particles of earth. This movement is referred to as "ground particle velocity."

Displacement - The distance that particles move when they are oscillating.

Velocity - How fast the particles move when they are oscillating. Since the velocity is continually changing, the peak or maximum velocity is the useful value that is reported. The peak particle velocity is expressed in inches per second.

Acceleration - The rate at which the particle velocity changes during oscillation. It is usually reported in feet per second squared.

A blasting seismograph records three levels of particle movement:

1. <u>Longitudinal</u> - This is the back and forth particle movement in the same direction that the vibration wave is traveling.

2. <u>Vertical</u> - Up and down particle movement perpendicular to the direction the vibration wave is traveling.

3. <u>Transverse</u> - Left and right particle movement perpendicular to the direction the vibration wave is traveling.

A study conducted by the Bureau of Mines and published in *Bulletin 656* reached the following conclusions:
1. Particle velocity is the best criterion for predicting the probability of vibration damage to structures.
2. Particle velocities less than 2.0 inches per second show little probability of causing structural damage, while particle velocities greater than 2.0 inches per second are more likely to cause damage.
3. If there are at least eight milliseconds (0.008) between detonations, the vibration effects of individual explosions are not cumulative.

Processes or procedures for minimizing vibration from blasting are as follows:

1. Use delay blasting to separate the explosives used in a blast into a number of individual detonations. If the interval between delay periods is at least eight milliseconds, the individual detonations can be treated as separate blasts and their vibration will not be cumulative.

2. Limit the weight of explosives per day period (more than eight milliseconds) in accordance with the Bureau of Mines and Commonwealth of Kentucky scaled distance equation.

$$W = (D/Ds)2$$

Where W is the safe weight of explosives in pounds and D is the actual distance in feet to the nearest structure of concern. Either determine an appropriate value for the scaled distance Ds by means of several instrumental blasts, or use a minimum value of 50 or 60.

3. Use less than the calculated safe weight of explosives for the first one or two periods in tight shots.

4. Use only the amount of subdrilling that is necessary to pull the bottom of the blast. As with boreholes that do not have adequate relief for the rock, much of the energy released by the explosives in the subdrilled part of a borehole will go into the production of vibration.

5. When limiting the weight of explosives per delay to a relatively low amount, it may be necessary to modify the blast design.

   a. Reduce the size of the blast by using small diameter, shallow boreholes. This will involve a commensurate decrease in burden and spacing and perhaps using several lifts to remove the rock to the desired length.

   b. In deep boreholes, use decked explosives charged with a different delay in each charge.

   c. A millisecond delay blasting switch can be used to increase the number of delays periods that are available for use in the blast.

Air blast is a compression wave that travels through the atmosphere in a manner similar to the way a P-type body travels through the earth. Air blast may be produced by one or more of two different mechanisms. The first is from the energy released directly to the atmosphere by the detonation of an unconfined explosive such as exposed detonating cord. The second occurs when the high pressure gaseous by-products from a confined detonation are released into the atmosphere. This can be caused by a mud seam, inadequate stemming, or insufficient burden.

It has been found that windows, probably the weakest part of a structure that will be exposed to air blast, usually suffer the most damage. Extremely high overpressures could also cause the formation of exterior masonry cracks or interior plaster and wall board cracks.

Attention must be given to both the structural damage and disturbance caused by air blast. Structural damage is a concern for obvious reasons, while disturbance, or annoyance, is considered a form of pollution by some environmental protection agencies. Annoyance can also lead to vibrations complaints and legal actions.

GENERAL BLASTING PRACTICES SAFETY

This section consists of the "do's and don'ts" of the explosive industry. It is the responsibility of all persons who handle explosives to know and follow all industry safety procedures.

— **Do not** place explosives where they may be exposed to flame, excessive heat, sparks, or impact.

— **Do not** allow unauthorized or unnecessary persons to be present where explosives are handled or used.

— **Do not** use any explosive unless completely familiar with the explosive, including the correct and safe procedures for its use.

— **Do not** carry explosives in the pocket of your clothing or elsewhere on your person.

— **Do not** use explosives or accessory equipment that are obviously deteriorated or damaged.

— **Do not** strike, tamper with, or attempt to remove or investigate the contents of a detonator, or try to pull the wires, fuse, or detonating cord out of any detonator or delay device.

— **Do not** insert anything but safety fuse in the open end of a blasting cap.

— **Do not** attempt to reclaim or use safety fuse, detonating cord, detonators, or any explosive that has been watersoaked, even if they have apparently dried out.

— **Do not** handle, use, or get near explosives during the approach or progress of any electrical storm. All persons should retire to a safe place. This applies to both surface and underground operations.

— **Do not** force a detonator into dynamite, cast primers, or boosters. Insert the detonator in a hole in the dynamite that is made with a punch suitable for that purpose. If the hole in the cast primer or booster is too small for the detonator, do not use the cast primer or booster.

— **Do not** make up primers in a magazine, or near other large quantities of explosives, and do not make more primers than are necessary for immediate needs.

— **Do not** force explosives into a borehole or through an obstruction in a borehole. This is particularly hazardous in dry holes and when the charge is primed.

— **Avoid** placing any part of your body over or in front of the borehole when loading and tamping.

— **Do not** slit, drop, deform, tamp, or abuse the primer or drop another cartridge directly on the primer.

— **Do not** return to the area of any blast until the smoke and fumes from the blast have cleared.

— **Do not** attempt to investigate a misfire too soon. Follow recognized rules and regulations. Wait 30 minutes when using electric caps and one hour if fuse caps are used.

— **Do not** drill, bore, or pick out a charge of explosives that have misfired. Misfires should be handled by or under the direction of a competent and experienced person.

— **Do not** fire a blast without a positive signal from the blaster in charge.

— **Do not** fire the shot from in front of the blast.

— **Do** make certain that all surplus explosives are in a safe place; all persons, equipment and vehicles are at a safe distance; all access routes into the area should be posted with guards; and adequate warning has been sounded.