Chapter 6
INITIATION

COMPONENTS USED IN ELECTRIC BLASTING

The electric power source used to initiate a blast may be a twist or push type generator blasting machine and a remote radio device, a condenser discharge machine, or an AC power line through a blasting switch. Never use batteries directly; only a blasting machine or blasting switch provides the current and time control necessary to prevent cap arcing and misfires.

The generator type blasting machine converts the mechanical energy of the blaster's hand motion into electrical energy and then closes the contacts to the firing circuit when the peak electric energy is generated. A condenser discharge machine uses dry-cell batteries to charge a set of capacitors. When the fire button is pushed, the stored electrical energy in these capacitors is discharged into the firing circuit. The remote detonation system can be activated and controlled with the commonly used King™ radio that has been retrofitted with a dual tone modulated frequency chip (DTMF). The entire remote detonation system allows the blaster-in-charge more flexibility in selecting a location to initiate the blast.

No alterations or repairs of an electric blasting machine should be attempted, unless by the manufacturer. Ordinary maintenance by the blaster should be limited to changing the batteries in the condenser discharge type machines and to lubricating the moving parts in the generator type.

The LEAD WIRE, or the FIRING LINE as it is sometimes called, connects the power source to the blasting circuit. It should be a two-conductor, insulated, solid copper wire (with exception of the multiconductor cable for a sequential blasting machine) and be at least 14-gauge thickness. The length will vary according to the size of the shot, but it should not be less than 500 feet. CONNECTING WIRE is made the same way as lead wire, but it is only 20-gauge, and is used for short distances between the lead wire and the cap leg wires to prevent the loss (shortening) of the lead wire from blast damage.

The LEG WIRES are the wires attached to the cap. Normally these wires are made of copper, iron or aluminum and are always covered with a plastic insulation. The leg wires come in assorted lengths and are color coded. Caps coming from the manufacturer are short circuited by a piece of foil connecting the ends of both leg wires. This foil is called a SHUNT and it affords some protection against the cap accidentally being fired by a stray current. The shunt should not be removed from the leg wires until the cap is wired into the blasting circuit.

An essential piece of testing equipment for electric blasting is either the BLASTING GALVANOMETER or the BLASTING OHMMETER. These instruments are specially designed for testing blasting cap circuits. They contain limiting resistors which prevent the machine battery from initiating a blasting cap. Use of any other instrument (unless designed for blasting use such as a blaster's multimeter), not specifically designed for blasting circuits, will likely cause electric blasting caps to fire. The purpose of this instrument is to allow the blaster to check the connections and condition of the caps, wires, connections and completeness of the circuit.

The blasting galvanometer has an indicator needle which measures resistance of the circuit to which it is attached. The greater the resistance being measured, the less distance the needle will travel full scale. Blasting ohmmeters, which are more accurate than galvanometers, have different scales and are read somewhat differently; follow the manufacturer's instructions.

The galvanometer should be tested before each use. This can be done by placing a single piece of wire across the two external terminals to short circuit them. Doing this should cause the needle to deflect to the maximum. If it does not, the battery usually needs to be replaced. Replace them with a battery exactly like the one that the manufacturer recommends, or one that is approved by the regulating agency. If the needle does not deflect properly, the instrument is faulty. Do not attempt to repair the galvanometer. In doing so, you may create a power source rather than a test instrument.

In testing a circuit, the blasting galvanometer is not sufficiently sensitive to determine whether each individual blasting cap has been connected into the circuit. However, the instrument will give the blaster an indication that the circuit is not shorted, open, or if there are any bad connections. A short in the circuit will cause the resistance measured to be less than expected. A loose or dirty connection will cause an excessively high resistance. If the needle does not move at all when testing the circuit, this indicates a break in the circuit. If more precise readings are needed, then the use of a BLASTER'S OHMMETER or a BLASTER'S MULTIMETER is recommended.

Factors Basic to Ohms Law

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

V = Voltage expressed in volts
I = Current expressed in amperes
R = Resistance expressed in ohms

Example: Blasting circuit resistance is equal to 24 ohms and voltage is 120 volts, the electric current will be 5 amperes:

$$I = \frac{V}{R} = \frac{120 \text{ volts}}{24 \text{ ohms}} = 5 \text{ amperes}$$

If the current (amperes) is high enough, all the caps will fire. If the current is too low, some or all of the caps might not fire.

Blasting Caps are designed to have a minimum firing current of 0.25 amps.

ELECTRIC BLASTING CAPS

The blaster-in-charge must conduct a thorough survey for stray currents and eliminate any dangerous currents before adopting any system of electric firing with electric blasting caps and before loading any holes.

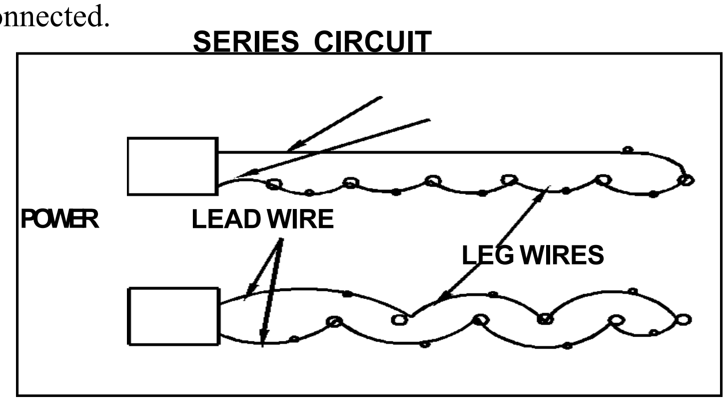
a. Keep shunt on detonators until ready to connect them in series.
b. Use only detonators of the same manufacture in the same circuit.
c. Use only delays or instant detonators in a series. Do not mix. Make up primers in accordance with

methods outlined in the *Institute of Makers of Explosives Publication No. 17*, "Safety in the Transportation, Storage, Handling, and Use of Explosives."

ELECTRIC BLASTING CIRCUITS

Commonly used electric blasting circuits are SERIES and SERIES-PARALLEL. Straight PARALLEL circuits are used in mines where firing is done by AC current through a blasting switch.

A SERIES circuit provides a single path for the current to flow through, containing all caps in the circuit. Holes or charges are commonly connected in series by connecting a leg wire of the cap in the first charge to one leg wire from the second charge, then to the third charge and so on. After all caps have been connected in this manner, only two leg wires will be left (one leg wire from the first cap, and one leg wire from the last cap). These two wires are then connected to the firing line and back to the power source. Electric blasting caps have color coded leg wires to help the blaster avoid confusion and to allow a visual check that all caps are connected.



(Figure 6-1) Diagram of series circuit

In cases where the distance between the caps is greater than can be spanned by the leg wires, connecting wire or detonating cord may be used to join the caps. The blaster can also use caps with longer leg wires which is the best solution. When connecting wire is used, there are more splices, which increases the resistance of the circuit and can cause unbalanced loads between caps. The increased number of splices also increases the possibility of error, takes more time, and costs more. The advantages of a single series circuit are:

1. All caps in the series receive the same current.
2. It is simple, both electrically and physically, so it is easy to lay out and difficult to make mistakes in wiring.
3. It is very easy to check a simple series with a blasting galvanometer.

The primary disadvantage to a series is that the number of caps is limited by the cumulative nature of each cap's electrical resistance in this kind of circuit.

A SERIES-PARALLEL circuit is one in which two or more series circuits are wired onto the same firing line in a parallel configuration (see Figure 6-2). It has the advantage of allowing a much larger number of caps in an electrical initiation design. This results from the way electricity overcomes resistance. Simply stated, the resistance of the cap circuit in a series circuit is the resistance of one cap multiplied by the number of caps in the circuit. In comparison, the resistance of the cap circuit in a series-parallel circuit is the resistance of one series circuit divided by the number of series in the total circuit.

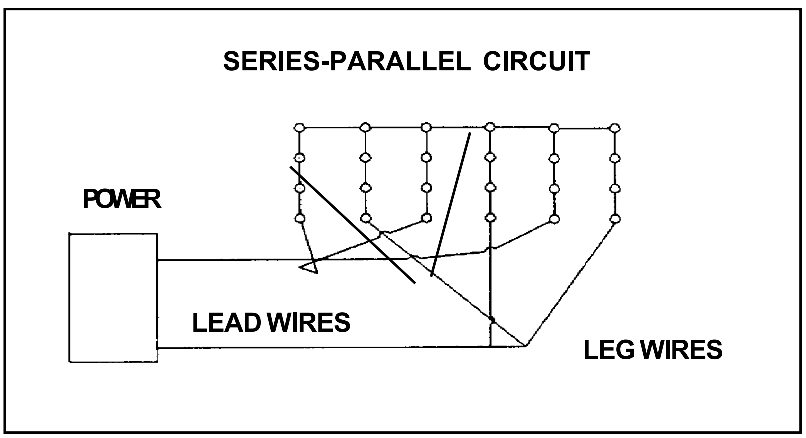
For example:

Series with 10 1.5-ohm caps -
10 x 1.5 = 15 ohms circuit resistance.

Series-parallel, 2 series of 10 1.5-ohm caps each -
10 x 1.5 = 15 ohms divided by 2
= 7.5 ohms circuit resistance.

The disadvantage, however, to series-parallel circuits is twofold: The individual series must be balanced within 10 percent (three caps cannot be included in one series and seven caps in another), *and* the blasting machine used must be rated to handle the current requirement, which is higher than for series circuits. The recommendation of the machine manufacturer must be followed. Do not use series-parallel circuits unless you are absolutely certain of what you are doing.

PARALLEL circuits, due to their complexity (multiple interdependent resistance calculations per cap) and high power requirements, are not used outside of major mine and tunnel operations, and are not further discussed in this publication.



(Figure 6-2) Series-parallel circuit.

SPLICING

Obviously, it is very important that all splices and connections are made carefully. A faulty connection may interrupt the current flow and cause a misfire. As mentioned before, splices add to the total resistance. Poor splices also reduce the tensile strength of the circuit's wires causing them to pull apart under strains the blaster must expect when loading and wiring up.

Before connecting any wires, the insulation must be removed carefully so as not to nick or cut the wire. The wire should be clean of any coating, dirt, or corrosion.

After splices and connections have been made, care must be taken so they do not short by contacting each other, ground or water. Bare wires and splices should be kept off the ground, using blocks of wood or nonconducting material. Uninsulated wire should not be in contact with the ground at any time.

The most frequent wire connection in blasting is joining the leg wires of the blasting caps in a circuit. The most common method of doing this is:

1. Hold the two bared wires together, side by side, with both ends pointing in the same direction.

2. Bend both together at the middle of the bared portion, folding in a way to form a loop.

3. Then twist this loop several times.

This forms a strong and a low resistance connection. This connection takes only a few seconds and tends to become tighter if pulled.

There are many other connections used in the field today. Any connection will work as long as it has strength and contact to provide low resistance.

The blaster-in-charge has the responsibility for wiring the circuit and making all splices and connections. This will keep the wiring consistent and will keep unnecessary traffic from the shot area so as not to trip over and break connections.

Primers

A primer is the explosive unit (cartridge, cast primer) which contains a detonator (blasting cap, detonating cord).

General

NEVER prepare more primers than immediately needed.

NEVER prepare primers in a magazine or near large quantities of explosive materials.

NEVER slit, drop, twist, or tamp a primer.

NEVER use a cast primer or booster if the hole for the detonator is too small.

NEVER enlarge a hole in a cast primer or booster to accept a detonator.

NEVER punch explosive material that is very hard or frozen.

NEVER force a detonator into explosive material.

Making Primers With Electric Detonators

<u>Small Diameter Cartridges</u> (less than 4 inches in diameter) (Figure 6-4):
Step 1. Punch a hole straight into one end of cartridge.
Step 2. Insert the detonator into the hole.
Step 3. Tie leg wires around the cartridge using a half-hitch.
NEVER pull the wires too tightly. This may break them or damage the insulation.

<u>Large Diameter Cartridges</u> (4 inches and larger in diameter) (Figure 6-4):
Step 1. Punch a slanting hole from the center of one end of the cartridge coming out through the side two or

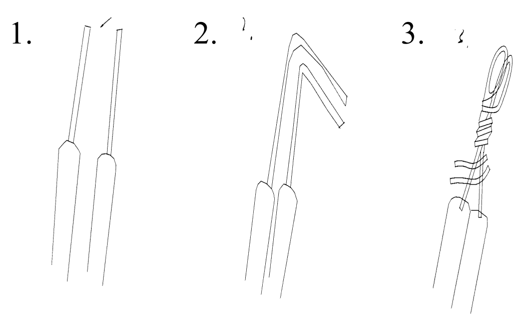
more inches from the end.

Step 2. Fold over the leg wires about 12 inches from the detonator to form a sharp bend.

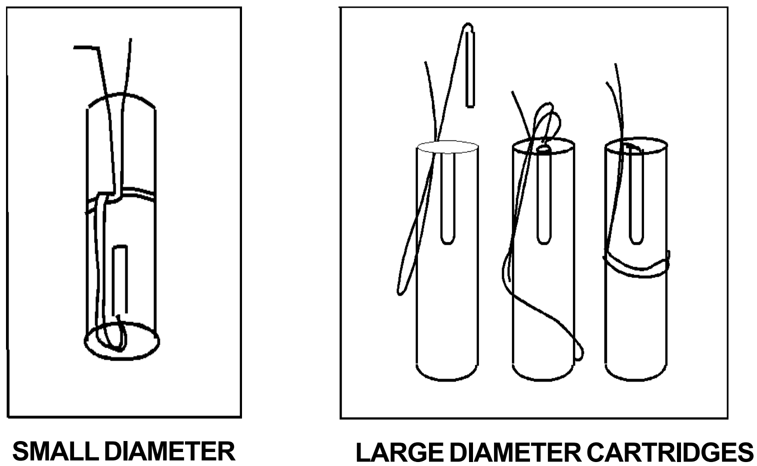
Step 3. Push the folded wires through the hole starting at the end of the cartridge and coming out through the side.

Step 4. Open the folded wires and pass the loop over the other end of the cartridge.

Step 5. Punch another hole straight into the end of the cartridge beside the first, insert the detonator in this hole, and take up all the slack in the wires.



(Figure 6-3) Bare leg wires.



(Figure 6-4) Cartridge Diameter

Exploding Bridgewire Detonators (EBWs)

Exploding bridgewire detonators (EBWs) are not subject to detonation by static electricity, stray currents, radio transmitters, etc., and may be safely used where these conditions are present.

Exploding bridgewire detonators and firing sets are manufactured by Reynolds Industries and are approved for NPS use. RP-80, RP501, and RP-83 detonators may be used with detonating cord, or bulk explosives, or cartridges of cap sensitive explosives. RP-80 detonators with cord adapters are used only with detonating cord. RP80 and RP501 detonators are directional, whereas the RP 83 detonators are not.

Use Reynolds FS-9 or FS-10 firing sets in accordance with the manufacturer's instruction.

Consult Reynolds Industries before firing more than two EBWs in series.

Provide enough lead wire to permit the blaster and crew to be at least 500 airline feet from the nearest explosive. Always follow the manufacturer's recommendations for wire gauge and type.

Detonating Cord

Select a detonating cord consistent with the size and physical condition of the borehole, stemming, and the type of explosive.

Typically, 50-grain down line is used in boreholes. Twenty-five grain down line also works since it is easier to tie and less expensive.

Handle and use detonating cord with the same respect and care given other explosives.

Cut the line of detonating cord extending from a borehole or from a charge from the supply spool before loading the remainder of the borehole or placing additional charges.

Handle and use detonating cord with care to avoid damaging or severing the cord during and after loading and hooking up.

Make sure detonating cord connections are complete and positive in accordance with manufacturer's recommendations.

Make knot-type or other cord-to-cord connections only if the explosives core is dry (See Figure 6-5).

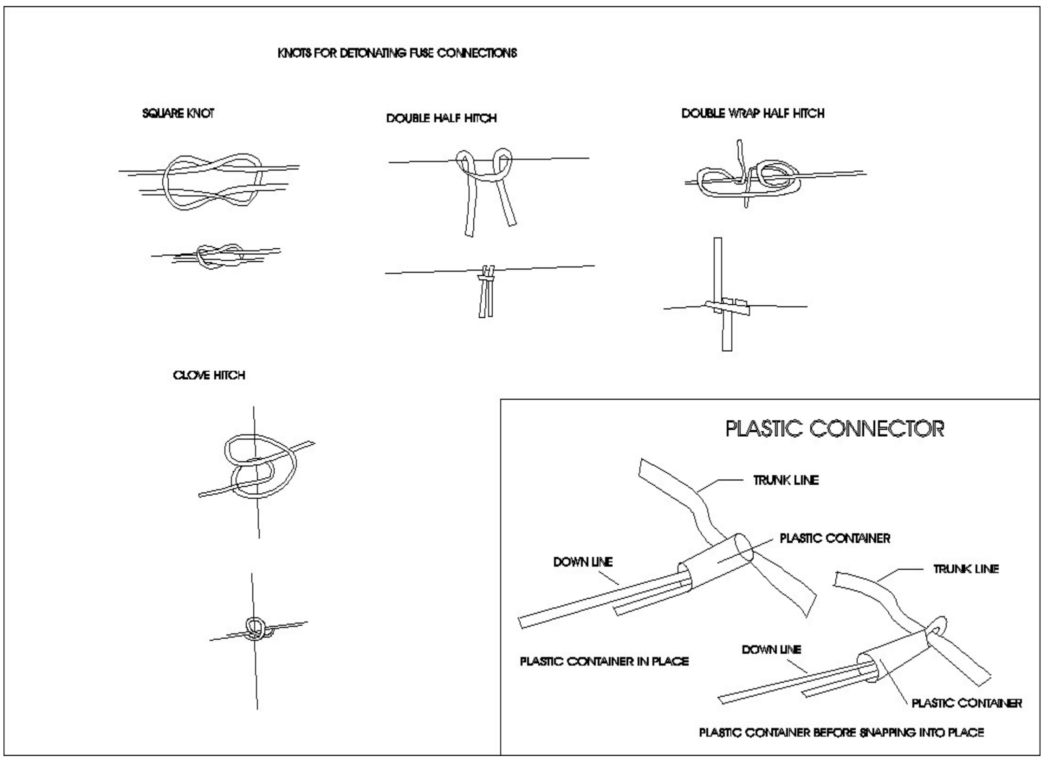
Keep all detonating cord trunklines and branchlines free of loops, kinks, or sharp angles that direct the cord back toward the oncoming line of detonation. Be sure to weight the cord.

Inspect all detonating cord connections before firing the blast.

When using detonating cord millisecond-delay connectors or short-interval-delay electric blasting caps with detonating cord, strictly follow manufacturers recommendation when connecting a detonator to detonating cord, tape or otherwise attach the cap securely along the side or end of a three-foot length of detonating cord. The end of the detonator containing the explosive charge must be pointed in the direction in which the detonation is to proceed. Tie the "pigtail" to the main line just before returning to the blasting machine.

Do not bring detonators for firing the trunkline to the loading area or attach them to the detonating cord until everything else is in readiness for the blast.

When detonating cord is used, a double line of cord with frequent crossties should be used throughout, so that the detonation wave can reach the explosive charges from more than one direction. (See Figure 6-6).

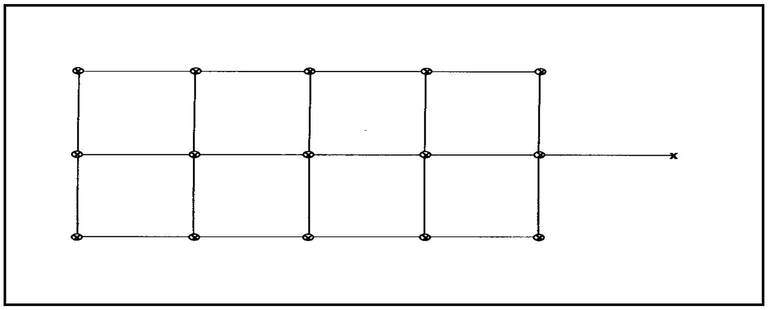


(Figure 6-5) Detonating cord connections.

DRILLING

Do not start drilling until all remaining butts or old holes are examined for unexploded charges. If any are found, refire them before work proceeds. <u>Never deepen drill holes</u> that have contained explosives or blasting agents.

Make boreholes large enough to admit the explosives cartridges freely. Check holes before loading to determine depth and conditions. Do not drill within 50 feet of a hole loaded with explosives.



(Figure 6-6) Double-trunking.

LOADING

Establish procedures that permit safe and efficient loading before loading is started. Do not load any holes, except those to be fired in the next round of blasting. After loading, immediately remove all remaining explosives and detonators from the blast area.

Tamp only with blunt wood rods or plastic tamping poles without exposed metal parts. Non-sparking metal connectors may be used for jointed poles. Avoid violent tamping. Never tamp the primer. Tamp the last half of stemming material firmly in place. Take care not to damage detonator wires or detonating cord.

In blasting operations, no drill holes shall be sprung or chambered.

Never leave loaded holes unattended or unprotected. Blasters must schedule work to ensure loaded holes or charges will be shot before they leave the site.

Never leave explosives or blasting agents unattended at the blast site.

Only tools used for loading explosives into holes should be nearby when explosives are delivered. Keep machines and other
equipment out of the area. Do not operate equipment within 50 feet of loaded holes.

The only activity permitted in a blast area is that required for loading holes with explosives.

If more than one blaster has been loading holes in the same area, the blaster-in-charge will check the wiring to ensure that all charges are properly connected in the circuit.

WIRING

Wire all caps in series. Do not wire more caps in a series than the rated capacity of the blasting machine.

For multiple shots, use standard 14-gauge or larger solid copper wire with no bare joints. Tape splices and support them off the ground. When using 20-gauge firing line, on other than EBW systems, get regional blasting officer approval.

Provide sufficient lead wire to permit the blaster and crew to be a minimum of 500 airline feet away from the nearest explosive charge.

Prevent lead wires and detonator wires from contacting any part of a telephone line, transmission line, or other electric installation.

After lead wires have been wired into the circuit with all connections tight and the wire clean, and before attaching lead wires to the blasting machine, check the circuit with an approved galvanometer or an approved blaster's ohmmeter to see if it is closed.

FIRING

The blaster-in-charge must be assured that everyone is in a safe location. The blaster-in-charge is the last person to leave the blast area.

Use only approved capacitor discharge or generator blasting machines.

The blaster-in-charge of the shot shall connect the lead wires to the blasting machine.

Where practical, keep the blasting machine in a moisture-proof, locked box, and remove only when used.

Be sure safety switches are in the same position before connecting lead wires.

The blaster-in-charge is responsible for the blasting machine when it is not in use on the project.

Firing Procedures

a. Personnel must not be in front of the shot; they should be off to one side at least 500 airline feet from the nearest explosives. Vehicle and pedestrian traffic approaching the blasting area by road or trail must be stopped at least 700 airline feet from the blasting area when the first "fire" is given, and held until the area is cleared by the blaster-in-charge.

b. The blaster-in-charge must shout "fire" three times before each shot, and sufficiently in advance to permit all persons to reach a point of safety. Refer to the complete firing sequence in Chapter 5 - Blast Area Security.

c. Where noises make shouts inaudible, use bullhorns, whistles, or low-wattage radios. If radios are used when blasting with electric caps, observe the minimum distances shown in Tables 6-1 through 6-5. These limits on radio use do not apply when using EBWs or Nonel.

d. All personnel must face the blast, with backs to the sun if possible, to provide the best chance to watch for and avoid flying debris. The must also be in the safest direction from the blast to avoid fumes.

e. Immediately after the blast, the blaster-in-charge disconnects the lead wires from the machine, twists the bare ends together, and secures the machine so it cannot be activated.

Transmitter Power (1) (Watts)	Minimum Distance Feet)
Up to 4,000	750
5,000	850
10,000	1,200
25,000	2,000
50,000(2)	2,800
100,000	3,900
500,000	8,800

(1) Power delivered to antenna.
(2) 50,000 watts is the present maximum power of U.S. broadcast transmitters in this frequency range.

(Figure 6-7) Recommended distances for commercial AM Broadcast transmitters 0.535 to 1.605 MHz.

Effective Radiated Power (Watts)	Minimum Distance (Feet)
Up to 10,000	600
1,000,000	2,000
5,000,000 (1)	3,000
100,000,000	6,000

(1) Present maximum power channels 14 to 83 – 5,000 000 watts.

From Institute of Makers of Explosives, Publication 20, Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Electric Blasting Caps (March 1971)

(Figure 6-8) Recommended distances from UHF TV transmitters.

Transmitter Power (1) (Watts)	Minimum Distance Feet)
100	750
500	1,700
1,000	2,400
5,000	5,500
50,000	17,000
500,000(4)	55,000

(1) Based on the configuration shown in Fig. 2b using 20.8 MHz which is the most sensitive frequency.
2) This table should be applied to International Broadcast Transmitters in the 10-25 MHz range.
(3) Power delivered to antenna.
(4) Present maximum for International Broadcast.

(Figure 6-9) Recommended distances for transmitters up to 30 MHz (excluding AM broadcast). Calculated for a specific loop pickup configuration.

Transmitter(1) Power (Watts)	MF 1.6 to 3.4 MHz Industrial	HF 28 to 29.7 MHz Amateur	VHF 35 to 36 MHz Public Use 42 to 44 MHz Public Use 50 to 54 MHz Amateur	VRF 144 to 148 MHz Amateur 150.8 to 161.6 MHz Public Use	UHF 450 to 470 MHz Public Use
10	40	100	40	15	10
50	90	220	90	3s	20
100	125	310	130	50	30
180(2)	·	·	·	65	40
250	200	490	205	75	45
500(3)	·	·	290	·	·
600(4)	300	760	315	115	70
1,000(5)	400	980	410	150	90
10,000(6)	1 250	·	1,300	·	·

Citizens 8and (Walk e-Talkie) 5 watts Minimum Distance 5 ft–26 96 to 27 23 MHz

(1) Power delivered to antenna.
(2) Maximum power for two-way mobile units in VHF (150.8 to 161.6 MHz range) and for two-way mobile and fixed station units in UHF (450 to 460 MHz range).
(3) Maximum power for major VHF two-way mobile and fixed station units in 35 to 44 MHz range.
(4) Maximum power for two-way fixed station units in VHF (150.8 to 161.6 MHz range).
(5) Maximum power for amateur radio mobile units.
(6) Maximum power for some base stations in 42 to 44 MHz band and 1.6 to 1.8 MHz band.

(Figure 6-10) Recommended distances of mobile transmitters including amateur and citizens' band minimum distance (feet).

Effective Radiated Power (Watts)	Minimum Distance (Feet) Channtels 2 to 6 and FM	Channels 7 t0 13
Up to 1,000	1,000	750
10,000	1,800	1,300
100,000 (1)	3,200	2,300
316,000 (2)	4,300	3,000
1,000,000	5,800	4,000
10,000,000	10,2000	7,400

(1) Present maximum power channels 2 to 6 and FM 100,000 watts.
(2) Present maximum power channels 7 to 13–316,000 watts.

(Figure 6-11) Recommended distances for VHF TV and FM broadcasting transmitters.

Static Electricity

Take precautions to prevent accidental firing of electric blasting caps from current induced by radar, radio transmitters, lightning, adjacent power lines, dust storms, clothing, portable electric cables for equipment, or other sources of extraneous electricity.

a. Do not throw electric blasting cap leg wires through the air. Unfold or unroll near the ground.

b. Shunt EBC detonators in holes that have been primed and loaded until wired into the blasting circuit.

c. Do not load boreholes when an electrical storm is in progress or approaching.
   (1) If holes are loaded and a storm occurs, keep the danger area clear and post flaggers in the same manner as shots are fired.
   (2) If holes are loaded, but not connected to the lead wire, do not shunt the series; leave it open.

d. Use detonating cord or other nonelectric system in place of electric blasting caps in power line areas. If the current cannot be interrupted, use EBWs or nonelectric detonators on work within 300 feet of the line. EBWs and non-electric detonators must also be used within the minimum distance (as described in *IME Publication No. 20*) from a permanent radio or TV transmitting station (See Tables 6-1 through 6-5).

e. Clothing - Although not a major cause of accidental detonation, clothing can generate enough static electricity to detonate electric blasting caps. The most hazardous condition occurs when wearing clothing of different fabrics, particularly wool when worn with dacron or nylon on a dry, cold day. Take these precautions:
   (1) Wear cotton or wool. Avoid wearing synthetics such as dacron or nylon, particularly with wool garments.
   (2) Do not remove coat or sweater while working with detonator.
   (3) Discharge static electricity by grounding body for at least five seconds.
   (4) When hazardous amounts of static electricity exist, use EBWs or nonelectric initiation systems.

BLASTING WITH SAFETY FUSE

NPS-65 prohibits the use of all cap and fuse devices.

BLASTING WITH DETONATING CORD

Detonating cord is a linear form of a high explosive. Unlike black powder, detonating cord contains a core of a very high-velocity explosive that detonates (rather than burns) at a speed of about four miles per second. The core is usually PETN, a high explosive with a velocity of about 22,000 feet per second.

When detonating cord explodes, it sends a shock wave along its entire length which is capable of detonating any cap sensitive high explosive that it comes in contact with. About four inches of detonating cord has the same power as a No. 8 strength blasting cap.

There is less risk in handling and loading when using detonating cord than there is when using caps. However, any blasting system is hazardous. Blasting safety depends on the training and experience of the blaster.

Detonating cord firing systems are often substituted for electric methods of firing under conditions when stray current or radio frequency energy may present problems for electrical blasting.

Most cords detonate at speeds of 21,000 to 24,000 feet per second. The speed depends on the manufacturer, the content of the powder train and the cord loads. These loads can vary from 18 to as high as 400 grains per foot. Most popular loads are 25, 40, or 50 grains. Detonating cord resembles safety fuse in appearance. However, you cannot light detonating cord with a match. The cord, like most other explosives, needs an initiating device. The usual method is a fuse cap or electric blasting cap taped securely to the side of the detonating cord, pointed in the direction the explosive is to follow, or travel down the cord.

The main line of detonating cord, which runs through the area where you have placed explosive charges, is called a "trunkline." Lines of cord which run from this trunkline to the individual charges are called "downlines" or "branchlines."

Priming with Detonating Cord

The first cartridge to enter the hole is usually fixed as a primer. This provides a length of detonating cord running the full length of the main charge to the primer at the bottom.

The most common method of priming small diameter cartridges with detonating cord is to punch a deep hole in one end of the cartridge, tie a half-hitch knot in the end of the cord, and insert the knotted end into the hole. The cord is then bent and passed along the cartridge and taped there with plastic tape.

Or, the blaster can punch a downward angled hole completely through the cartridge at about the middle of the cartridge and another hole in the bottom as before. The blaster then runs the cord through the angle hole and inserts the knotted end in the bottom. The cord is then pulled to tighten the cord in the cartridge.

Joining Detonating Cord

In preparing a detonating cord firing system, trunklines must often be extended; branch and downlines must be tied into the trunklines. This calls for tying knots in the detonating cord.

Different types and makes of cord are more flexible and easily tied than others. For connecting lengths of detonating cord, such as in extending a trunkline system or attaching a pigtail, the common square knot is recommended.

For connecting downlines to trunklines, a double-wrap half- hitch or "girth hitch" is most commonly used.

All knot connections must be tight to provide close contact between the two pieces of cord. Plastic connectors are available to make connections in the grades of detonating cord that are difficult to tie.

All lines tied to a trunkline should be at right angles to it. If this is not done, the cord could be thrown off or cut off before it is initiated.

Detonating Cord Firing Systems

For instantaneous firing, the trunkline is unreeled so that it lies across the top of the holes to be fired. It should be reasonably slack to facilitate tying knots.

For two rows of charges, the cord is unreeled in the same manner, but the cord is joined together. This minimizes the chances for misfires.

More rows may be added in the same manner, with the addition of crossties to create a complete circuit, and two waves traveling in two directions around the circuit.

Delay Firing with Detonating Cord

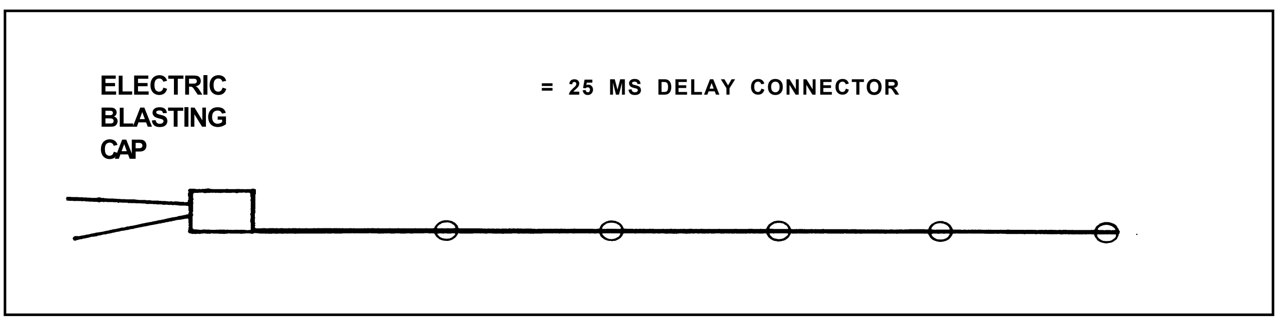
Delay firing with detonating cord is a little more complicated than with electric blasting caps, but still not that difficult. The major problem with detonating cord delays is the possibility of cutoffs. This is because the timing delays are on the surface of the blast area. This exposes the delays to ground movement and flying rocks.

Usually, the greater the delay, the greater the chance for a misfire from trunkline cutoff. This dictates that cutoff problems can be avoided by using the shortest delays possible within the design limits of the blast. The rule of thumb is <u>one millisecond per foot of spacing</u>. Therefore, if the holes were 15 feet apart, the delay should be 15 milliseconds or less. If the material to be blasted is seamy or naturally broken, the delay should be further reduced. However, a number of interrelated factors affect blast performance, including type of explosive, per-hole load, in-hole load distribution, and per-delay-interval load; the actual delay interval selected must be based on all these factors.

One of the safest and most efficient methods of delay firing with cord occurs with the use of millisecond delay connectors inserted in the trunkline, just before the downline leading to the hole to be delayed. The connectors are molded plastic sleeves fashioned so that detonating cord can be looped and locked into place with a tapered pin at each end. They contain a copper tube delay element in the center. These delay connectors can also be a molded plastic connector block, containing the delay element, connected by a short piece of shock tubing. The cord is connected to the connector blocks on each end of the delay connector. These connectors are delay timing mechanisms which interrupt the normal speed of detonation of the trunkline by a specific amount of time. The connectors contain sensitive explosives and should be treated and stored the same as a blasting cap. When placed into the detonating cord trunkline, they should be placed as close as possible to the hole they are delaying (but at least six inches away from the downline knot). Therefore, they are least likely to be disturbed by the detonation of the previous hole.

Normally, the millisecond connectors are available in either 9, 17, 25, 50 or 75 millisecond delays. When using the 25 millisecond connectors, the detonation takes 25 milliseconds to travel through each connector in its path. In the following diagram, there are five holes loaded and primed with detonating cord, using no delay connectors.

When the electric blasting cap is fired, the detonating cord carries the detonation so quickly that all five holes are considered to fire simultaneously. However, if a 25 millisecond delay connector is inserted in the trunkline before each hole except the first, the shot is broken into five separate delay intervals.

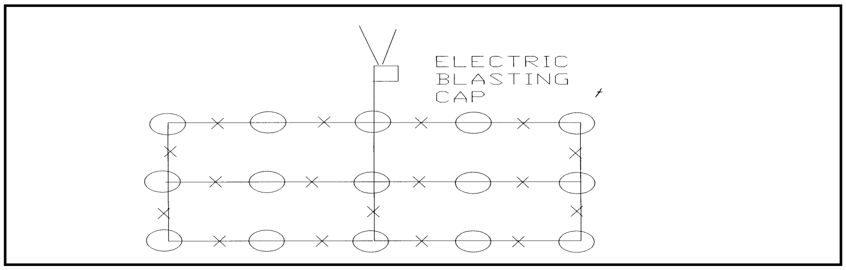


(Figure 6-8) A shot can be broken into five separate delay intervals.

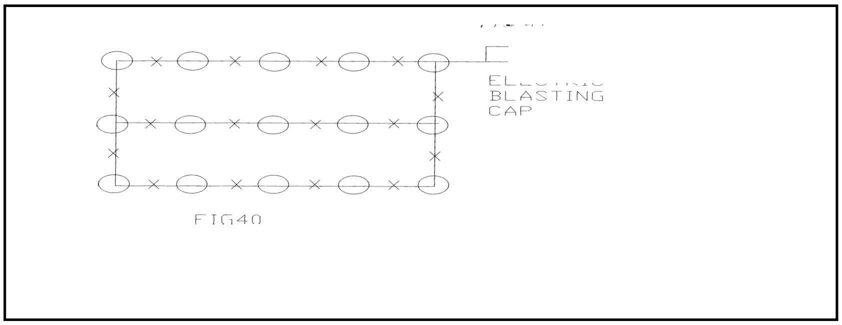
The first hole will detonate immediately with the blasting cap. The second hole will fire 25 milliseconds later because of the delay connector. The third will fire 25 milliseconds later than the second, or 50 milliseconds after the cap has fired; and so on. Incorporating delays into the detonating cord shots increase the fragmentation of the rock being broken and reduces potentially harmful ground vibrations (as does all delay systems).

In the following examples, patterns are laid out with millisecond connectors in various places to create delay patterns. The EBC indicates the point of initiation. The numbers above the borehole represent the time in milliseconds after the cap fires that the borehole will detonate. “X” represents the delay connector inserted in the detonating cord.

Note that there are a maximum of two holes per delay in the following pattern. If the delay connector is omitted on the crossties, the delay pattern becomes the “V cut.” The following is an example of the delay pattern for the so-called “V cut”:



(FIGURE 6-13) V-CUT DELAY PATTERN



(Figure 6-14) Square corner-cut delay pattern

In the previous delay pattern, there are five holes detonating with a 50 millisecond delay, i.e., a maximum of five holes per delay.

Another example is the square corner cut which has, in this case, a maximum of three holes per delay.

DETALINE DETONATING CORD SYSTEMS

The Detaline Delay System by Dupont:

The Detaline nonelectric initiation system utilizes a low energy detonating cord. The system can be used with conventional detonating cord downlines or nonelectric in-the-hole delays.

The Detaline system was developed because Dupont felt that there was a need for a reliable nonelectric initiation system that was both quieter and cheaper than standard detonating cord systems. The system consists of:

1. <u>Detaline Cord</u> - A low energy detonating cord, with a 1.4 grain per foot explosive core. This cord is cut from 2000 foot spools to any desired length of trunkline, or downline. The cord is extremely insensitive to mechanical impact. For example, a No. 8 strength blasting cap will not reliably side initiate the cord. The cord will not propagate through a knotted splice. To splice the cord, a Detaline starter is required. A starter is also needed to initiate the Detaline trunkline which extends into the blast pattern.

2. Detaline Starter - Consists of a lime green plastic body molded in the shape of an arrow. Positioned in the center portion of the plastic starter body is a nonelectric detonator with a sealed top closure. The tail end is designed to accept the insertion of a loop of Detaline trunkline. A short sawtooth pin locks the Detaline cord into direct contact with the detonator receptor. The arrow end accepts either a Detaline cord or detonating cord downline, or both, providing the detonating cord downline is looped behind it. Initiation of the Detaline trunkline instantaneously activates the internal explosive charge in the starter resulting in detonation of the base charge and cord locked into the pointed arrow end. The arrow end must always point in the direction of the intended detonation as the nonelectric detonator element functions in one direction.

3. Detaline M.S. Surface Delays - These delays consist of an arrow-shaped plastic body which contains a nonelectric delay detonator element. They are designed to give an accurate time delay between activation of the tail end and detonation of the cord locked in the arrow end. Because the delay element functions only in one direction, the means of initiation must be from the tail end. The hookup is identical to the starter. The delays are used to connect segments of detaline trunkline to form sequentially delayed blasting patterns. The six different delay periods are color coded for easy identification and consist of 9, 17, 30, 42, 60 and 100 milliseconds.

4. Detaline M.S. In-Hole Delay Connectors - These detonators consist of a cylindrical aluminum, shell containing base, priming, and delay explosive charges. The detonator resembles an electric blasting cap except for a special top closure that is designed for insertion of a Detaline cord. A delay tag is affixed to the shell of each detonator for identification of the delay period. Nineteen delay periods from 25 to 1,000 milliseconds are available. The in-hole delay detonator is connected to the Detaline cord downline by inserting the cord into the top closure. The cap and cord can be laced through or half-hitched around a cartridge of cap sensitive explosive (do not use dynamite with this system). The complete primer assembly is lowered into the hole and the Detaline cord downline cut from the spool, leaving enough cord at the collar to attach the Detaline starter.

Hookup procedures for the Detaline system are similar to those used with conventional detonating cord trunklines and M.S. connectors. More elaborate delay sequences are possible when the surface and in-hole delays are used.

NONELECTRIC INITIATION SYSTEMS

These systems are a product of the explosive industry trying to create new methods to provide the blaster a better choice of delay systems and allow compliance with the new laws, or to simply provide a system for their particular needs. These systems may use parts or principles of the older delay systems or products, but essentially they are new systems, with new products.

The Nonel (registered trademark) System by Ensign Bickford

The NONEL system consists of a thin plastic tubing (.12 inch) with a thin coating (one pound per 70,000 feet) of a reactive material on the inside surface. When initiated, this tube will reliably transmit a low energy signal or spark from one point to another by means of a shock wave similar to a dust explosion. It will reliably propagate this detonation around sharp bends and through kinks. Because the detonation is sustained by such a small quantity of reactive material (.1 grains per foot), the outer surface of the tube remains intact during and after functioning.

Nonel can be initiated by detonating cord, blasting caps, or a percussion cap, and is used in conjunction with the Nonel Lead-in, which is a continuous length of shock tube.

Delay firing with this system is accomplished by using noiseless trunkline delays in conjunction with detonating cord downlines or long lead H.D. Primadets. The system consists of:

1. The Nonel shock tube.

2. The blasting cap with integral millisecond delay element, which initiates the detonating cord downlines or pigtails, or the long lead H.D. Primadets.

3. The Bunch Block for hookup to downlines and Primadets. The block contains the blasting cap with the delay element.