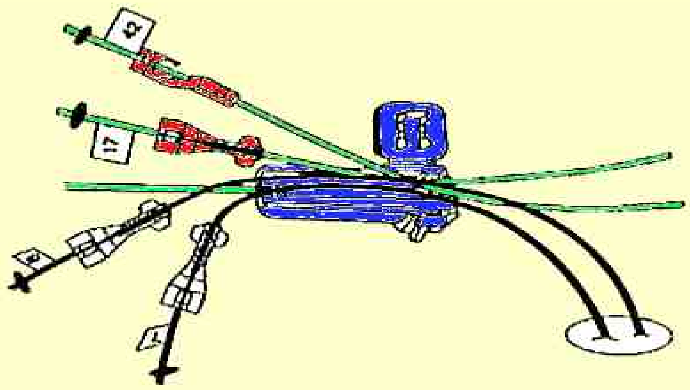
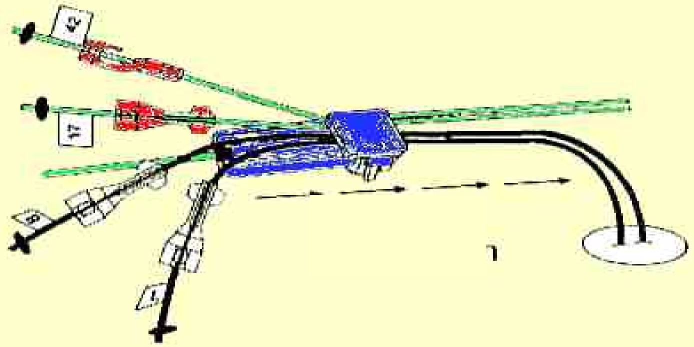
Initiation Systems





This blaster-training module was put together, under contract, with Federal funds provided by the Office of Technology Transfer, Western Regional Office, Office of Surface Mining, U.S. Department of the Interior, located in Denver, Colorado.

The module is an example of the technical assistance the Federal government furnishes States to assist them in meeting the requirements of the Surface Mining Control and Reclamation Act of 1977, upon which their State surface coal-mine regulating programs are based. In particular, the module was requested and will be used by the Sheridan District Office, Wyoming Department of Environmental Quality, Land Quality Division.

A word of caution: please note that **this module is not intended to stand alone, nor is it a self-training type module**. Rather, **the information the module provides MUST BE SUPPLEMENTED** by information given by a certified blasting instructor.

DISCLAIMER

The technologies described in the module are for information purposes only. The mention herein, of the technologies, companies, or any brand names, does not constitute endorsement by the U.S. Department of the Interior's Office of Surface Mining.

Initiation Systems

This module presents information pertaining to initiation systems currently used in blasting operations at surface coal mines.

Initiation Systems

The discussions of various initiation systems that follow concentrate primarily on common practice and safety.

Good results at any blasting operation can be achieved only when the initiating devices used to detonate explosive charges are of the highest possible quality, carefully chosen, and properly used to meet the task at hand.

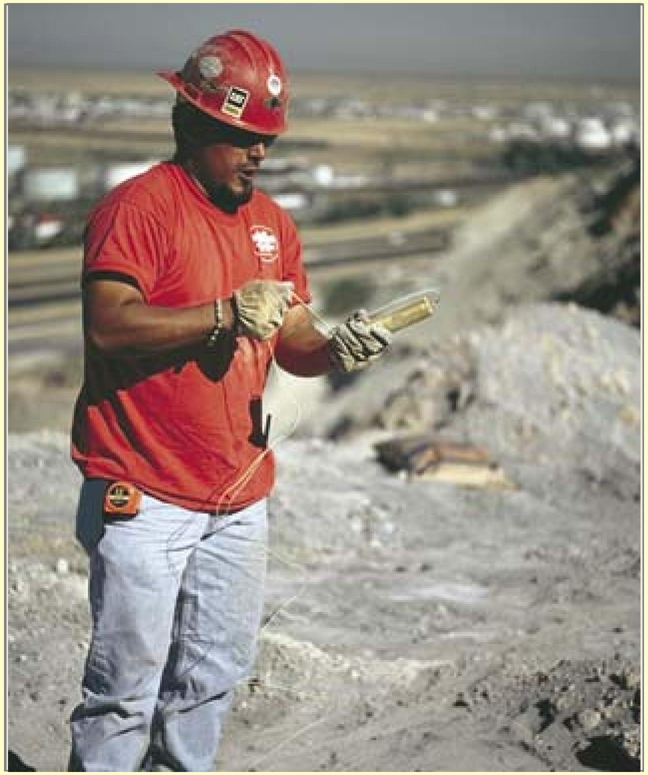
Unfortunately, initiating devices cannot differentiate between energy supplied purposely and energy supplied accidentally.

For this reason, users of such devices have the responsibility to maintain strict control of them over the course of their storage, transportation, and use.

Introduction

Initiation devices have evolved into a variety of systems offering more flexibility and increased safety over their earlier counterparts.

The use of non-electric systems eliminates the danger of premature detonation owing to radio-frequency energy or stray electricity in areas where **stray current** is a concern.



Modern, high-energy blasting machines are designed to provide a surplus of firing energy and reduce the possibility of **misfires**.

Introduction

In order to choose the right initiation system for a blasting operation, certain considerations, ensuring safe and effective blasts, must be taken into account.

The discussion of initiation systems that follows concentrates on common practice and the various "tricks of the trade" that are associated with each individual system. It is highly recommended that you confer with the manufacturer before finalizing your initiation program, so that you have a full understanding of the individual system at your operation.

Introduction

As a general rule, before you choose an initiation system, you should familiarize yourself with numerous site-specific factors at your operation. Consider the following topics and use them with manufacturer recommendations to evaluate:

- Geology (rock properties and structure);
- Geometry (typical pattern dimensions);
- Vibration (recommended criteria, including regulations), in particular,
  - Peak particle velocity and
  - Frequency;
- Airblast (recommended criteria, including regulations);
- Fragmentation (with respect to blasting goals);
- Explosive performance (know your explosive!); and
- Borehole conditions (water, voids, weak walls, etc.).

Introduction

An initiation system provides the initial energy required to detonate an explosive used for rock blasting. Initiation systems require:

- An initial energy source,
- A distribution network to deliver the energy to each blasthole, and
- An in-hole component to initiate a detonator-sensitive explosive.

The systems are broadly classified as either **electric** or **non-electric** and may contain various combinations of cord and initiators either as separate components or integrated.

Introduction: Initiators

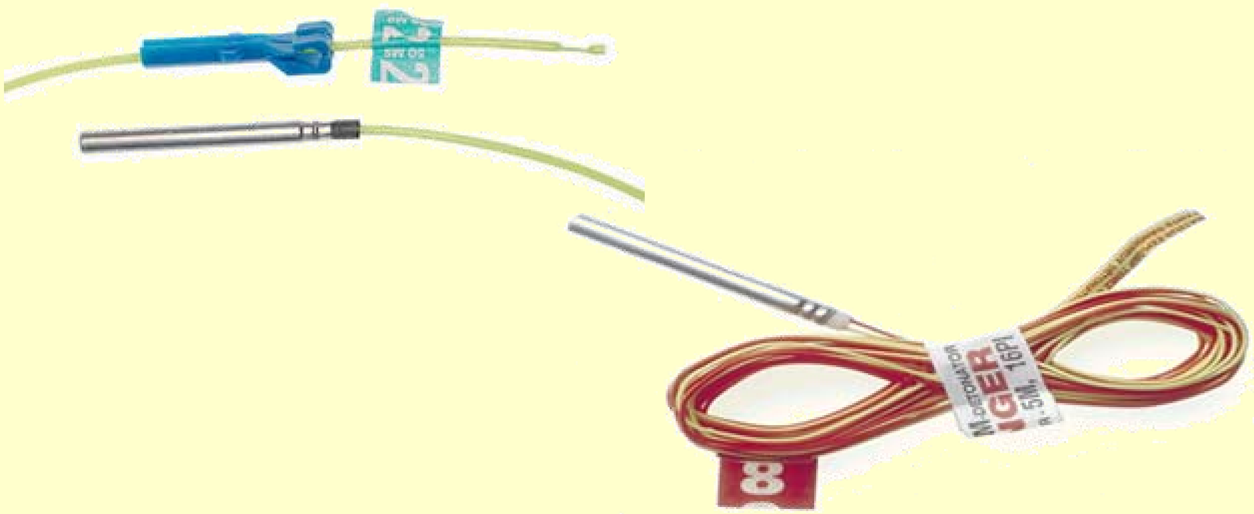
Initiator is a term used in the explosive industry to describe any device that may be used to start a detonation or a deflagration. There are four general classifications of initiators currently being used in surface coal-mine blasting:

- Non-electric systems,
- Electric systems,
- Electronic systems, and
- Blasting-cap and safety-fuse systems.

Introduction: Detonators

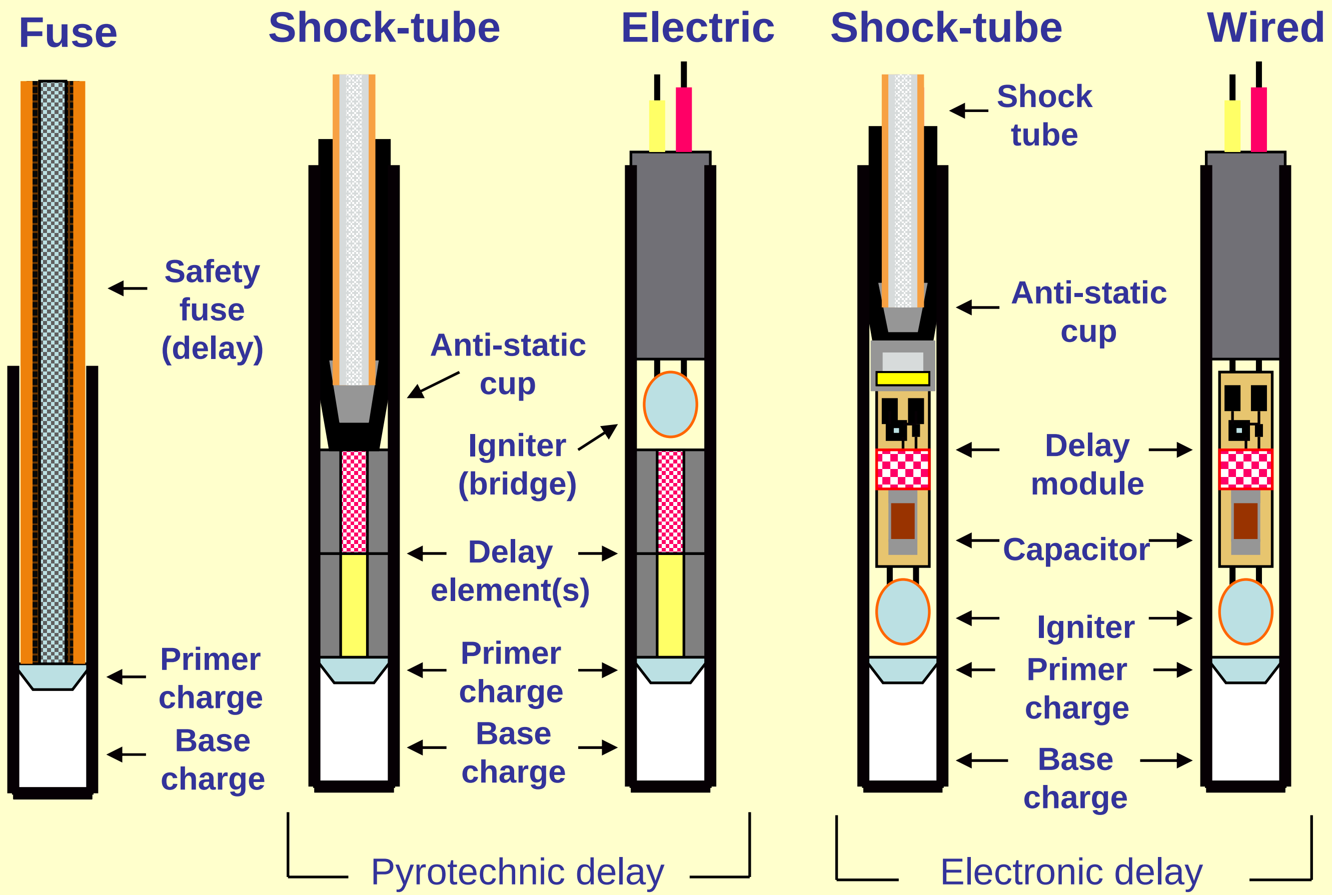
Detonators are devices used to initiate high explosives.

A detonator is a complete explosive initiation device that includes the active part of the assembly (usually enclosed in a metal shell) and the attached initiation signal transmitter (for example, leg wires, a shock tube, or other signal-transmitting material).



Detonators are either instantaneous (no time-delay element), millisecond (ms) delay, or long-period delay. Ms delays are commonly used for surface-mine blasting and are manufactured with delay times up to 500 ms. Long-period delays are available for periods up to several seconds.

Introduction: Types of Delays

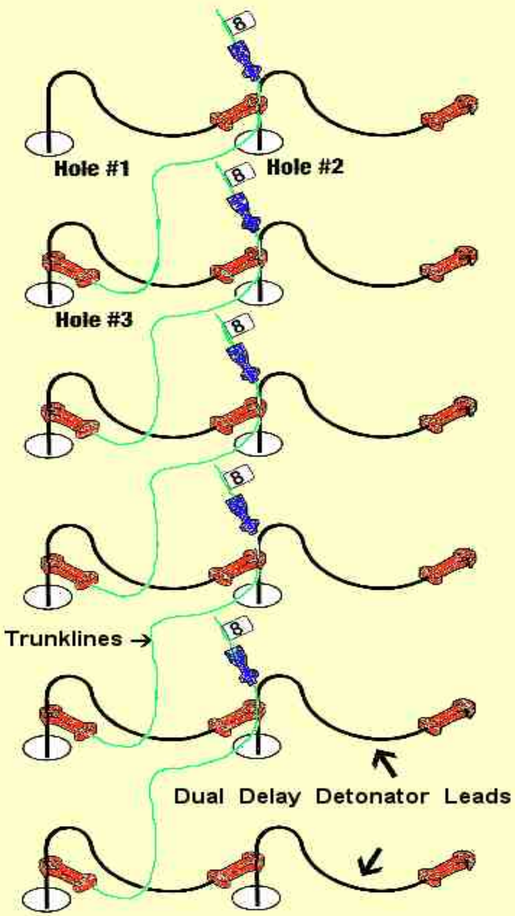


Introduction: Shock-Tube Systems

Choose a shock-tube initiation system for operations with:

- Stray current hazards,
- Static-electricity hazards (including wind, low humidity, plastic liners, etc.),
- Small-diameter holes (resulting in explosive densensitization,
- Sequential precision desired,
- Timing flexibility, and/or
- A need to reduce inventory.

Avoid using a shock-tube initiation system for operations with extreme loading conditions. Also, a mechanical or electrical check is a MUST for matting shots and burying shots undertaken using shock-tube initiation.



Introduction: Shock-Tube Systems

Assuming you decide to initiate your blast using a shock-tube system, you should take into account several considerations:

- Loading conditions:
  - Cord or shock tube downline
  - Borehole size
  - Type of shock tube
- Sleep times of shock tube
- Explosive's sensitivity:
  - Cord/shock tube
  - Dead-pressing potential
- Level of reliability:
  - Redundancy on surface
  - Redundancy in the hole
- Level of precision:
  - Common in-hole delay *v.* variable in-hole delay
  - Twin-path
- Level of accuracy:
  - Lot-to-lot
- Dual-delay *v.* down-hole and surface systems:
  - Pattern
  - Flexibility
  - Safety

Introduction: Detonating Cord

Choose detonating cord for operations with:

- Extreme loading conditions
- Multiple priming requirements

Avoid using detonating cord in small-diameter boreholes, where explosive damage or disruption might result. Also, a detonating cord used with an explosive that is too sensitive may trigger a premature initiation. Detonating cord can desensitize an explosive. And, finally, because uncovered detonating cord on the surface is very loud when fired, it may not be appropriate for use in a noise-sensitive environment.

Introduction: Electrical Blasting Systems

You might choose an electrical blasting system if you are undertaking matting shots or if your operation requires circuit testing. However, these situations are unlikely, and, currently, because of their susceptibility to extraneous electrical hazards, electrical blasting systems are not recommended or acceptable for use in Western coal-mine States. Specifically, electrical circuits are vulnerable to stray current potential, static hazards, and radio-frequency hazards.

Instead, detonating cord, shock-tube systems, or electronic systems are the preferred safe means for initiating blasts at surface coal mines in the West.

Electric detonators are used frequently in surface coal mines to initiate detonating-cord trunk lines. Accordingly, their safe use will be discussed in this module.

Introduction: Electronic Systems

Choosing an electronic blast-initiation system is a large step for any surface coal mine. With the possibilities of increased productivity improvements, increased security, design flexibility, and system control also comes an increased level of product complexity. Each electronic system requires a unique understanding of its standard-operation and hook-up procedures. The advantages of an electronic blast-initiation system include its:

- Precision and accuracy,
- Blast-management capability, and
- Increased security.

The disadvantages of an electronic blast-initiation system are that:

- It requires increased training,
- It is more complex, and
- It is more expensive.

Non-Electric Systems

Typical non-electric systems used today consist of detonating cord, shock-tube detonators, or a combination of the two. These systems are extremely popular in Western coal mines and are sold by all the major explosive manufacturers in the United States.

Non-electric initiation systems have safety advantages, principal among them an immunity to **stray electrical currents** and **radio frequencies**. However, these systems are susceptible to accidental initiation by a lightning strike. Non-electric detonators contain sensitive **ignition charges** and **base charges** and can be accidentally detonated by heat or impact.

Non-electric systems require an orderly hookup, and careful visual inspection is necessary to verify the continuity of the system.

Non-Electric Systems

The Institute of Makers of Explosives' (IME's) recommendations with respect to non-electric detonation systems are:

- **ALWAYS** use a detonating cord matched to the blasting methods and type of explosive materials being used;
- **NEVER** make loops, kinks, or sharp angles in the cord, all of which might direct the cord back toward the oncoming line of detonation;
- **ALWAYS** handle detonating cord as carefully as other explosive materials;
- **NEVER** damage detonating cord prior to firing;
- **ALWAYS** cut the detonating cord from the spool before loading the rest of the explosive material;
- **NEVER** attach detonators for initiating a blast to detonating cord until the blast area has been cleared and secured for the blast;
- **ALWAYS** make tight connections, following manufacturer's directions;
- **NEVER** use damaged detonating cord;
- **ALWAYS** attach detonators to detonating cord with tape or by means of a method recommended by the manufacturer;
- **ALWAYS** point detonators toward the direction of detonation;
- **ALWAYS** attach detonators at least 6 inches from the cut end of the detonating cord; and
- **ALWAYS** use a suitable booster to initiate wet detonating cord.

Detonating Cord

Detonating cord is round, flexible cord containing a core of pentaerythritol tetranitrate (PETN) high explosive. The exterior sheathing is waterproof material surrounded by a reinforcing textile/plastic wrapper.

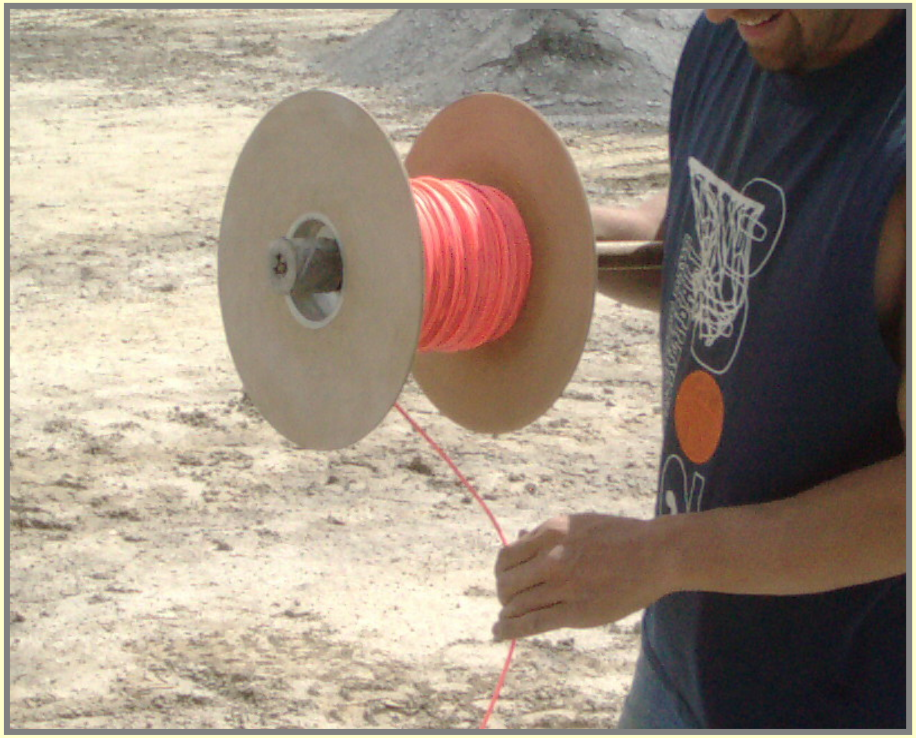
The purpose of detonating cord is to:

- Detonate other high explosives with which it comes in contact and
- Transmit a detonation wave from one detonating cord to another or to a non-electric detonator.

Detonating Cord

Detonating cord is available for a wide range of core loads, and many variables must be considered when determining the proper core-load detonating cord to use. These variables include:

- The detonation velocity of detonating cord is 22,000 feet per second;
- Core loads are typically 2 to 400 grains per foot; and
- There are 7,000 grains in 1 pound of PETN.



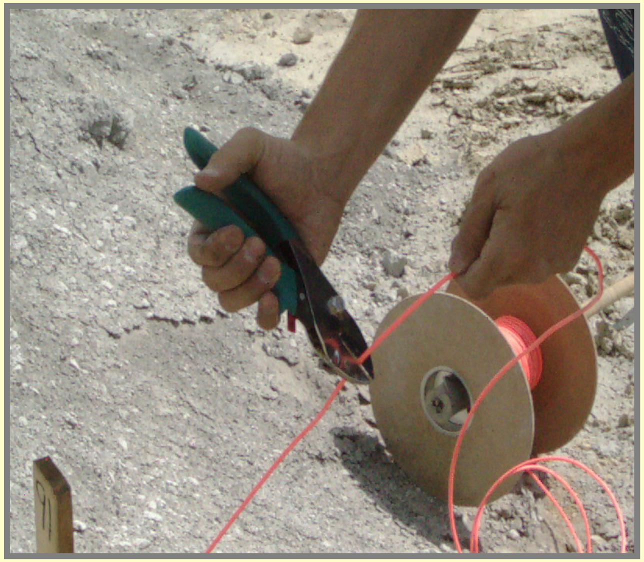
Detonating Cord

A general rule when selecting detonating cord is to use the lowest cord load possible consistent with conditions at hand.

Low cord loads will carry the same signal with much less **air blast** and disruption of the explosive column. If the detonating cord is in contact with **ANFO** or ammonium nitrate-based products, a lower core load will have less disruptive effects on the explosive column and will result in greater **blast efficiency**.

When determining the core load to use at your blasting operation, consider:

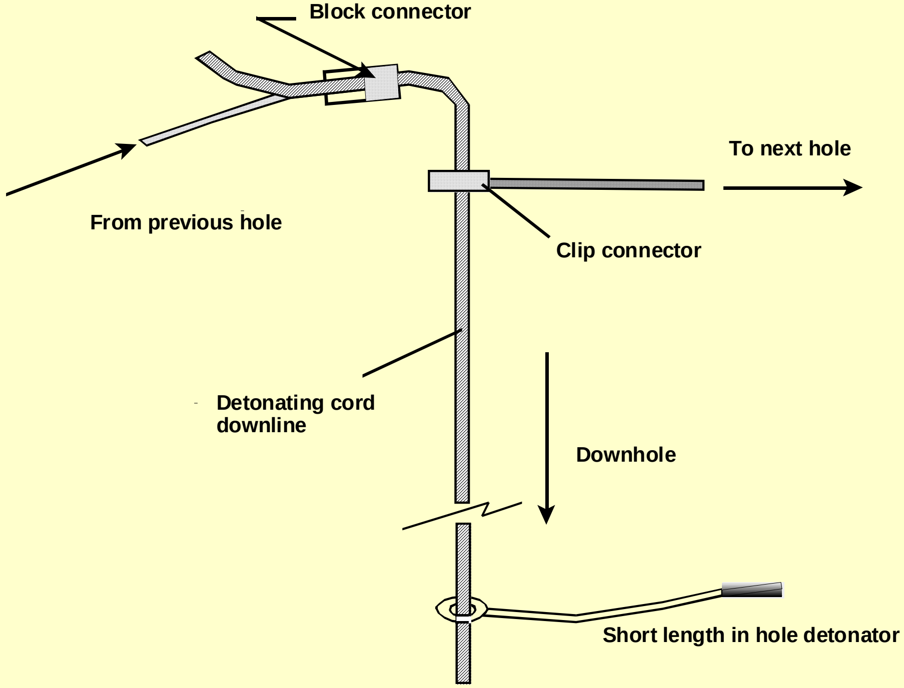
- What will initiate the cord?;
- What will the cord initiate?;
- The weather;
- The explosives used for the main blasting charge;
- The use of detonator-sensitive or nitroglycerin-based explosives; and
- The diameter of the hole.



Detonating Cord

Detonating cord can be used as **downlines** or **trunklines**. As downline, detonating cord is used to initiate cord-sensitive boosters or ms-delay detonators.

When selecting downline detonating cord, check with the manufacturer of your booster to determine the minimum recommended core-load detonating cord for reliable detonation. In addition, ***check with the manufacturer to determine the correct detonating cord for your borehole conditions.***



Detonating Cord

Initiating Detonating Cord

Even though modern detonators are very dependable, it is a good idea to use two detonators at the point of initiation, especially when delay detonators are used for surface initiation of multiple hole shots.

For maximum reliability, detonators should be attached to a short length of detonating cord or pigtail, which in turn is tied into the system with a recommended knot just before the blast. Most detonating cord is designed to be initiated with an electric detonator, a non-electric detonator, or two cap-and-fuse assemblies.

Advantages of Using Detonating Cord

Detonating cord is easy to use, rugged, and insensitive; it is not susceptible to electric hazards; and it is reasonably accurate.

Disadvantages of Using Detonating Cord

Detonating-cord misfires and cut-offs can occur from flyrock or sub-surface rock shifting; downward initiation through the charge column can both cause low-order deflagration and render the charge more dense, even to the point of “dead press;” and detonating cord can disrupt stemming material.

Review Questions and Discussion

1. Identify the advantage(s) of initiating a blast using a totally non-electric shock-tube system.
    a. Such a system will not disturb the explosive column
    b. Such a system is insensitive to lightning
    c. Such a system is insensitive to static electricity
    d. All of the above

2. The numbers identifying various sizes of detonating cord refer to the number of grains of __ that are contained within a single linear __ of cord.
    a. Cord; inch
    b. Explosive; foot
    c. Explosive; pound
    d. Black powder; foot

3. True or false: detonating-cord downlines can decrease the efficiency of the blasting agent the detonating cord is intended to set off?

Answers

1. d. correct.

2. b. is correct.

3. True. A detonating-cord downline does tend to decrease the efficiency of the blasting agent the detonating cord is intended to set off. This is because, when detonating cord shoots, it can burn and deadpress part of the explosive around it, thereby destroying part of the explosive column.

Detonating Cord

When attaching the detonator, be sure that its loaded tip is pointed in the direction you want the detonating cord to detonate (initiation can only be ensured in the direction the detonator is pointing). If you are using an electric detonator, wrap the cord and detonator securely together with electrician's tape at the desired point of initiation, at least 8 inches from the cut end of the cord.

If you are using a non-electric lead-in line, place the detonating cord pigtail in the **bunch block** parallel to the detonator, wrap the detonating cord around the bottom of the bunch block, back in the bunch block parallel to the detonator, and snap the lid firmly closed.

To use a cap-and-fuse assembly, place the detonators of the two assemblies side by side and attach them securely to the detonating cord. Tie a pigtail assembly to the detonating cord downline at the intended point of initiation using one of the recommended knot connections.

A recommended practice is to end-prime a wet detonating cord. Detonating cords are much less sensitive when they are wet. A straight length of cord will continue to detonate reliably, wet or dry. Side priming is not reliable for wet cord.

The only recommended methods of wet-end initiation are end priming with a No. 8 strength (or higher) detonator or using a high-velocity booster such as a cast booster or an 80-percent gelatin dynamite.

Detonating Cord

One downline is usually adequate for small-, medium-, or large-diameter holes. However, two downlines are recommended in deep, large-diameter blastholes loaded with multiple boosters that are separated by blasting agents or other non-detonator-sensitive explosives. In addition, two downlines are recommended when blastholes are **decked**. To help prevent cut-offs when using multiple downlines, keep them separated in the borehole and free of slack.

Detonating cord should be spliced together with a conventional square knot.

DO NOT SPLICE DOWNLINES. Splices are never recommended in the downlines inside a borehole, because failures can result from:

- The damaging of the splice during loading or stemming operations,
- Penetration of water through the exposed cord ends, or
- Cracks in the cord's covering around the knot.

Detonating Cord

As a trunkline, detonating cord is used to initiate surface-delay units such as ms-delay connector detonators, trunkline delays, and downlines.

When selecting trunkline detonating cord:

- Check with the manufacturer to determine what core load detonating cord will initiate surface connections and recommended knots and
- Determine the correct trunkline detonating cord to use with your surface delays for a delayed pattern.

The manufacturer will recommend a core load and proper hook-up methods.

Detonating Cord

Knots, Connections, and Layouts

Detonating cord is easy to connect for a blast. Most detonating cords will transmit a detonation reaction between sections spliced or joined together securely and tightly with the proper knots. Proper knots will reliably initiate most cords used in surface-mining applications. (The exception here would be that some light-grain cords may not initiate reliably through knots or splices. Consult the manufacturer of your detonating cord when splicing or connecting unusually large- or small-grain detonating cord.)

When connecting detonating cord sections together:

- **Make sure the cut ends are free of water, oil, or other contaminants.** Place all connections or detonators **at least 12 inches** (0.3 meters) from the exposed (cut) end to be sure of positive initiation. **This includes all knots, ms-connector blocks, and short-lead detonators.**

- **Make sure all the connections are at right angles.** Avoid sharp angles, which can cause the cord to cut itself off. Angle cut-off failures are caused when detonating cord branchlines or downlines slant back at an acute angle toward the main detonating cord trunkline. Explosive energy or fragments can sever a branchline or downline before the detonation wave reaches it through the knotted connection.

- **Do not kink, bend, scrape, or leave slack in the detonating-cord trunklines or borehole downlines or uplines.** The extra line extending out of the hole allows for **slumping** and is not confined as slack.

Detonating Cord

Knots, Connections, and Layouts—continued

- **Make all detonating cord knots tight and in contact so they cannot work loose.** Loose knots may fail to transmit the detonation wave. Avoid having knots in any downline cord.

- **Make sure every borehole has (1) two paths by which the detonation can reach it and (2) cross-ties between the trunklines at regular intervals frequent enough to provide positive detonation of the trunkline.** Cross-ties should be placed more frequently when the spacing and burden are small. Cross-ties are recommended insurance against trunkline cut-offs from ground movement or flying debris from holes that fire earlier in the shot's sequence.

- **Always cut off the excess cord or "tails" after tying in to prevent the initiation signal from crossing over the trunkline and cutting it off.**

- **Always keep the shot pattern as clear as possible of debris, boxes, box liners, explosives, etc., so that the trunkline layout is readily visible, distinctive, and neat.**

- **When several detonating cord downlines, uplines, or trunklines are used, make sure they do not cross over each other.**

Detonating Cord

Knots, Connections, and Layouts—continued

- **In locations that are close to residential or commercial sites, the noise from detonating cord trunkline may cause complaints.** This can be solved in a number of ways, including:
  - Eliminating the trunkline and initiate each downline at the surface with an electric or non-electric detonator,
  - Initiating a detonating cord upline from the bottom of a hole with an electric or non-electric detonator, or
  - Covering the trunkline with at least 12 inches of **fine** drill cuttings or dirt.

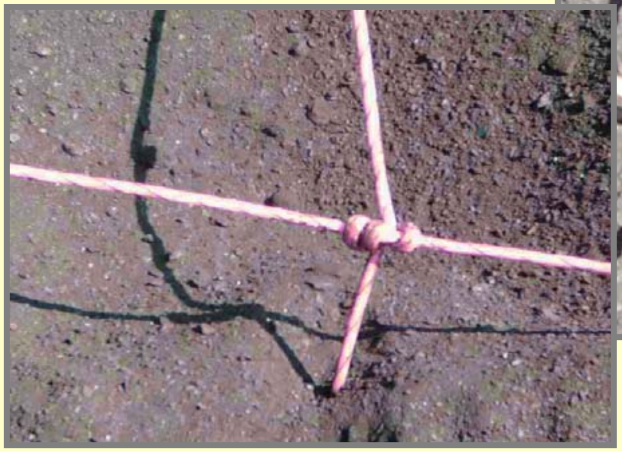
Detonating Cord

Right-Angle Connections

Connections between (1) downlines or uplines and a detonating cord trunkline, (2) cross-ties between trunklines, or (3) other right-angle hookups should be made with a double-wrap half-hitch (sometimes called a double-wrap clove-hitch).

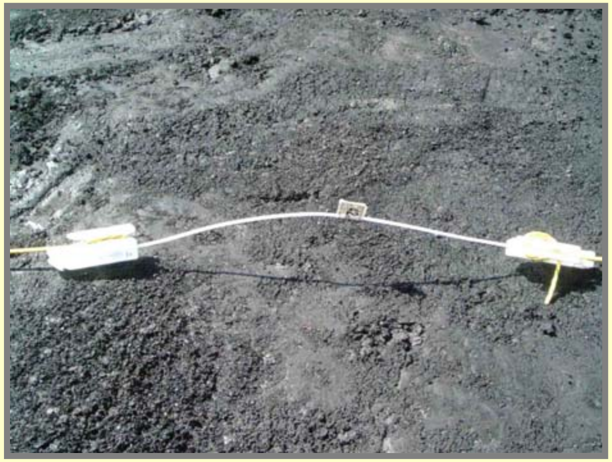
The most satisfactory connection between a stiff detonating-cord downline and a flexible trunkline is made by clove-hitching the trunkline around the downline or using a plastic detonating-cord connector.

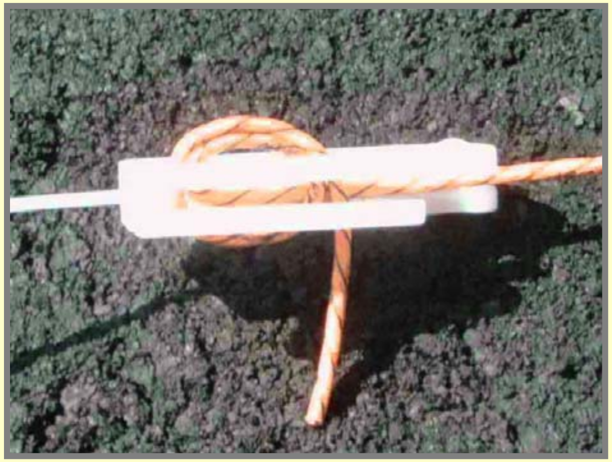
If there is no slumping or subsidence of the charge, the single-wrap clove-hitch is sufficient; however, single-wrap clove-hitches can be pulled out by slumping charges. This is prevented by clove-hitching the trunkline over a loop in the downline (instead of the single cord) and tucking the loose end through the loop at the top.



Detonating Cord

Instantaneous and Surface-Delay Systems





Instantaneous firing may still be done where vibration or airblast problems are not a concern. However, most blasts using detonating cord are delayed either on the surface or in the borehole by means of ms-delay techniques.

Surface-delay initiation, used without in-hole delays, is more vulnerable to failures or partial failures from ground movement than is surface-delay initiation used with instantaneous methods or in-hole delays.

The most common ways of surface-delaying a blast with detonating cord are:

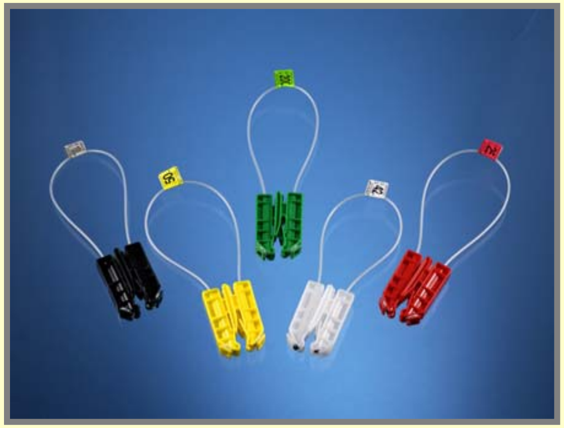
- Using ms-delay connectors in the detonating-cord trunkline,
- Using ms-delay electric or non-electric detonators attached to the cord downline, and
- Using surface shock-tube delay detonators.

Detonating Cord

Instantaneous and Surface-Delay Systems: Ms-Connectors

Ms-connectors allow an easy method of firing detonating-cord blasts by short-interval delays on the surface. These connectors come in a variety of delay intervals and are tied into a trunkline between the boreholes or between groups of boreholes to sequence the blast.

The rule of thumb is to allow 1 foot (0.3 meters) between holes for each ms of delay and always to locate ms-connectors either midway between holes or closer to the hole being delayed.



Although both the delay element and a high-explosive base charge are enclosed within a plastic block in an ms-connector, the connector should be protected from abusive shock, heat, impact, or friction (ms-connectors have an impact sensitivity equivalent to that of regular delay detonators). Be sure to clear unnecessary personnel and equipment from the shot area before ms-connectors are tied in.

Non-electric shock-tube detonators can be used in surface operations to reduce noise levels where the use of electric detonators is not an option. The **J hook** on the shock tube is connected to the first detonating cord in the sequence. The shock tube transfers the detonation between the boreholes to the delay detonator at the other end of the tube, which is connected to the next detonating cord downline.

Detonating Cord

Firing Surface-Delay Systems

Trunklines should be initiated with electric or non-electric detonators to maintain optimum control of the instant of firing. Use two detonators if the cord is wet.

The detonators are attached side by side along the detonating cord with the exploding ends pointing in the direction that the detonating cord will fire. Securely fasten the detonators with tape to ensure direct contact with the detonating cord. Care should be taken to prevent the end of the detonating cord from becoming wet where the detonators will be attached. A booster must be used if the core is wet and cannot be cut back to a dry core.

A recommended precaution is to first attach the detonators to a length of detonating cord about 18 inches long; such a cord is sometimes called a "pigtail." The pigtail can be placed several feet away from the main detonating cord until after unnecessary personnel have been cleared from the blast area and just before the scheduled blast time. For hookup, the pigtail can be tied onto the main trunkline by means of a square knot.

Click on the image above to play a clip showing detonation initiated by a coal-shot cord.

Review Questions and Discussion

1. Which, if any, of the cord sizes in this list will consistently initiate primers?
   a. 4.5-grain
   b. 7.5-grain
   c. 40-grain
   d. 50-grain
   e. None of the above
   f. All of the above

2. True or false: detonating cord on the surface of the ground can produce significant air blast?

3. What type of knot should be used to connect a detonating-cord downline to a detonating-cord trunkline?
   a. Half-hitch or clove-hitch
   b. Square knot
   c. Overhand knot
   d. Fisherman's knot

Answers

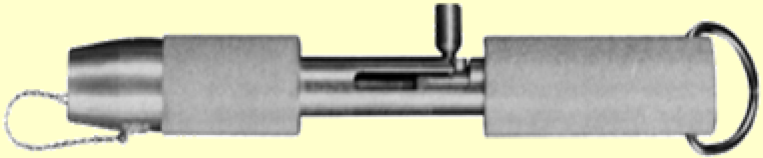
1. c. and d. are correct.
2. True.
3. a. is correct.

Shock-Tube Systems

Shock-tube systems use a small detonation in an almost empty plastic tube to transmit the initiation signal at approximately 6,500 to 7,000 feet/second (1,980 to 2,130 meters/second) throughout the blast pattern.

The plastic shock tube is composed of one or more layers of plastic, which are designed to enhance the tensile strength and abrasive resistance of the tubing. The inside of the shock tube is made of Surlyn™, which binds the thin interior coating of explosive dust (HMX and aluminum) to itself. A shock-tube system is highly insensitive to initiation by heat or impact and requires an intense, high-impulse shock to initiate the reaction.

Hand-held mechanical devices that use a shot-shell primer activated by a firing pin are frequently used, as well as devices that use a piezoelectric crystal to generate energy.



Shock-Tube Systems

Safety Considerations

The tubing in a shock-tube system remains intact after activation, unlike detonating cord, which is consumed in detonation. Shock-tubing may rupture during its initiation, and it is never advisable to hold the tubing in the hand during the initiation process.

Owing to the wide variety of shock-tube systems available, it is essential that the blaster (1) be knowledgeable about the system he or she is using and (2) follow the manufacturer's recommendations. Components from different types of systems should never be mixed in a single blast, unless specifically approved by the manufacturers.

Care must be exercised during the hook-up procedures. Omitting a charge or failing to make a connection will result in a misfire. Many surface-delay components produce a metal and plastic shrapnel when detonated. Most systems recommend covering the connections with dirt or drill cuttings to confine the shrapnel.

Vehicles such as bulk trucks must not drive over the tubing, connectors, or any surface components. No tools should be used to pry on any component containing a detonator, nor should any tool be used to open, close, fasten, or clean out any connector containing a detonator or detonating device.

Shock-Tube Systems

Many shock-tube system configurations are available from most explosive manufacturers. Ms trunkline delay assemblies are used for surface blasting. Many varieties of shock-tube delay detonators are available with a delay unit attached to one end of the tubing. Such a configuration can be used to generate individual-hole delays in a modified-series hookup.

Detonator timing includes the burn time of the shock tube.

Hole-to-hole and row-to-row timing can be introduced by using a combination of surface and in-hole units or a combination of dual-delay detonators with both an in-hole delay and a surface delay on the same unit.

Shock-Tube Systems

Shock-Tube Lead-in Line Detonators

A shock-tube lead-in line detonator allows for initiation of non-electric patterns from a safe distance. Factory assembled, spooled units with a detonator typically come in lengths of 75 to 1,000 feet (25 to 300 meters) or longer.

Ms and Long-Period Shock-Tube Detonators

Ms and long-period shock-tube detonators are used as in-hole detonating units or as delay units between holes in a row or rows in a blast. **NEVER** cut factory-assembled shock-tube detonators to attempt a splice or a surface connection.

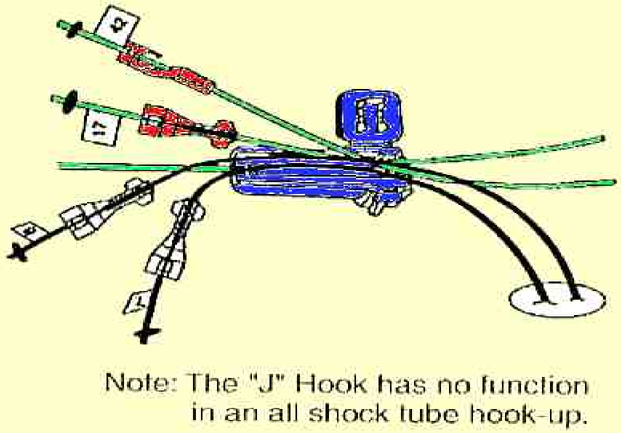
Shock-Tube Systems

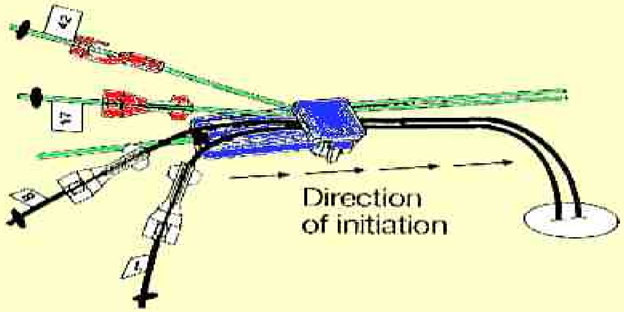
Shock-Tube Downlines with Shock-Tube Trunkline Delay Units

Shock-tube downlines can be used with surface trunkline delay units. Shock-tube surface-delay trunkline units use a plastic connector attached to a non-electric detonator with ms-delay timing.

To make the connection, crimp the detonator to a factory-assembled shock-tube of a certain length and charge all boreholes with the desired delay. To connect the boreholes, place the shock-tube downline and the shock-tube trunkline to the next hole in the plastic connector block or bunch block on the surface trunkline delay unit.

Close the hinged flap on the surface delay block, making sure that the tubes extend straight from the plastic block for at least 6 inches before they turn in any direction. Cover the connections with dirt or stemming material to reduce the possibility of shrapnel cut-offs.





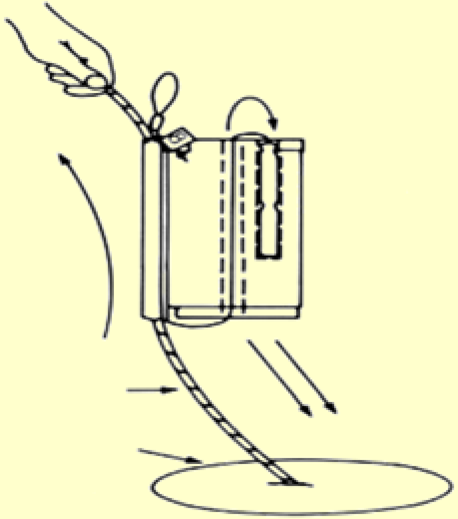
Shock-Tube Systems

Shock-Tube In-Hole Delays with Detonating-Cord Trunklines

Under this application, the boreholes are charged with the desired delays for the application and the main explosive charge is introduced. Then, the detonating-cord trunkline and the surface connectors are placed as needed for the blast. The detonating cord snaps onto the shock-tube in-hole unit via a J-connector. This connection replaces the knot a detonating-cord downline would have employed. The shock-tube must remain perpendicular to the detonating-cord trunkline.

Shock-Tube In-hole Delays with Detonating-Cord Downlines

Short-lead units are the most common type of in-hole delay used with detonating-cord downline. Typical short-lead units have 30 inches (76 centimeters) or more of shock-tube crimped to a delay detonator. The other end of the tube is looped to facilitate tying it to the detonating-cord downline.

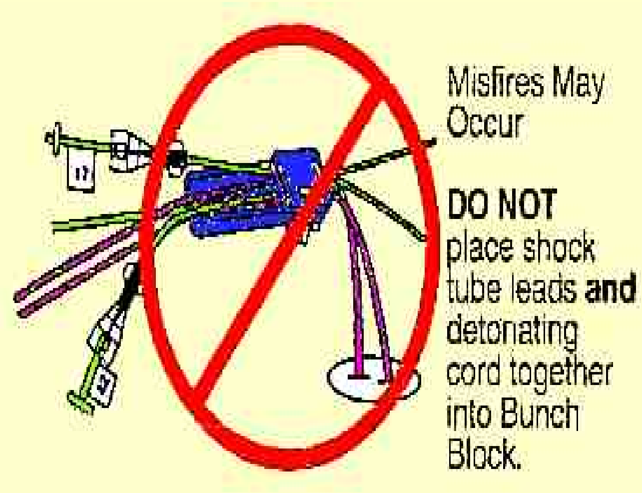


Short-lead units ensure bottom-hole initiation and have the added advantage of downhole delays. They may also be used to make sliding primers for double priming and/or decking applications. In this instance, the shock-tube is in contact with the detonating cord in the slider well of the cast-booster.

Shock-Tube Systems

Detonating-Cord Downlines with Shock-Tube Trunklines

When detonating-cord downlines are used with short-lead units, it is sometimes necessary to initiate detonating cord on the surface with shock-tube trunkline delays. Shock-tube is noiseless and allows for the design of many easy surface-delay patterns.



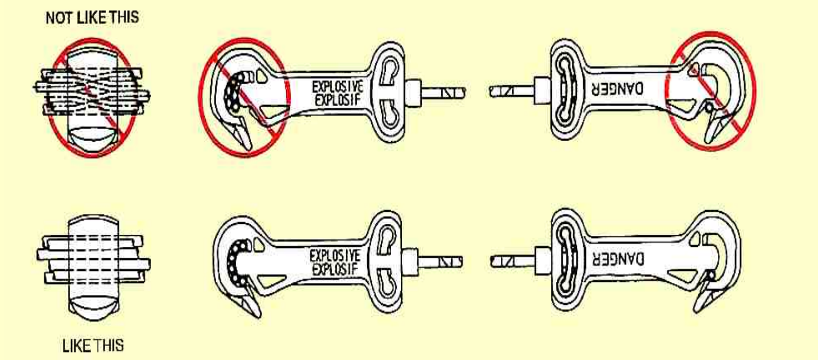
One end of a trunkline delay has a J-connector; J-connectors allow fast and easy connection to a detonating cord. The other end contains the bunch-block connection into which the detonating-cord downline is inserted. The end of the detonating cord should be knotted so the cord does not pull away from the bunch block.

The trunkline unit going to the next borehole or row is connected to the downline via the J-connector (make sure that adequate distance is maintained between the J-connector and the outgoing trunkline delay unit).

The detonating cord should extend straight from the bunch block. Trunkline delays should be covered with drill cuttings to prevent shrapnel cut-offs.

Shock-tube and detonating cord should never be placed in the same bunch block. The different propagation velocities of shock-tube and detonating cord will cause the shock-tube to cut off.

Shock-Tube Systems



Dual-Delay Detonators

The newest type of shock-tube detonator is rapidly replacing other shock-tube systems in many surface applications, especially where detonating cord is not used. Dual-delay detonators combine non-electric in-hole and surface initiation in one product. The in-hole detonator is a standard ms- or long-period-delay detonator, and the surface end contains a low-strength ms-delay initiator. The surface delay is housed in a plastic block clip that can be clipped to the shock-tube of the next hole in the blast pattern. All holes are loaded with the same in-hole delay detonators, and the surface units will also have the same delay. The desired timing is acquired by tying the holes together in the sequence that is needed for detonation. Rows can be tied together using a trunkline delay with bunch blocks or surface connectors.

Review Questions and Discussion

1. True or false: connections between blastholes using surface-delay detonators should not be made until immediately prior to clearing the blastsite?

2. The detonation velocity of a Nonel™ flash tube (which is a brand-name shock tube) is:
   a. 18,000 feet/second
   b. 1,800 feet/second
   c. 6,500 feet/second
   d. 65,000 feet/second

3. A shock-tube and a detonating-cord initiation system should ***NEVER*** be tied in together using this type of surface connection:
   a. Square knot
   b. J-hook
   c. Bunch block
   d. All of the above

4. True or false: a Nonel™ delay connector, which itself incorporates a detonator, must be stored with other detonators?

Answers

1. False. The blastsite should be cleared before initiating any tie-in of the pattern.

2. c. is correct.

3. a. is correct.

4. True.

Electric Systems

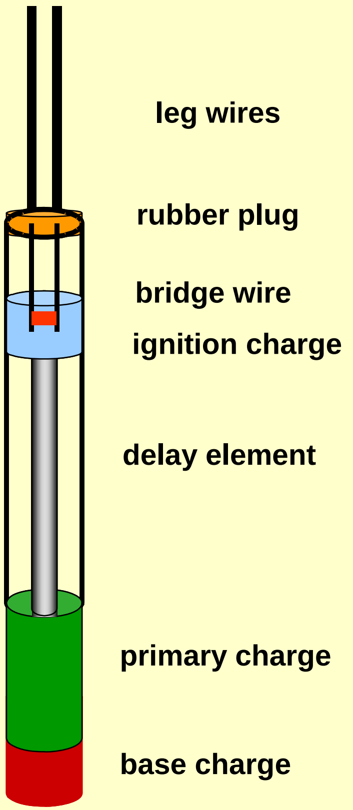
Typical electric systems used today consist of electric detonators connected in series, in parallel, or in a combination of the two.

The use of initiation systems that employ all-electric detonators is becoming very rare in surface coal mines and will not be covered in depth in this module.

This drop-off is use is largely owing to the vulnerability electric detonators have to stray current and radio frequencies.

The selection of the type of circuit to use with an electric-detonation system will depend upon the number of detonators to be fired and the type of operation. A simple series circuit is used on small blasts, consisting of less than 50 electric detonators. A series-in-parallel circuit is used when a large number of detonators is involved.

In almost every application, capacitor-discharge blasting machines offer the safest, most dependable, and most economical source of electrical energy for blasting.



Electric Systems

Four Principals

Successful electrical blasting depends upon four general principles:

- Proper selection and layout of the blasting circuit,
- Adequate energy source compatible with the type of blasting circuit selected,
- Recognition and elimination of all electrical hazards, and
- Circuit balancing, good electrical connections, and careful circuit testing.

Step-by-Step Field Procedures

The step-by-step procedures for checking a blasting circuit in the field are:

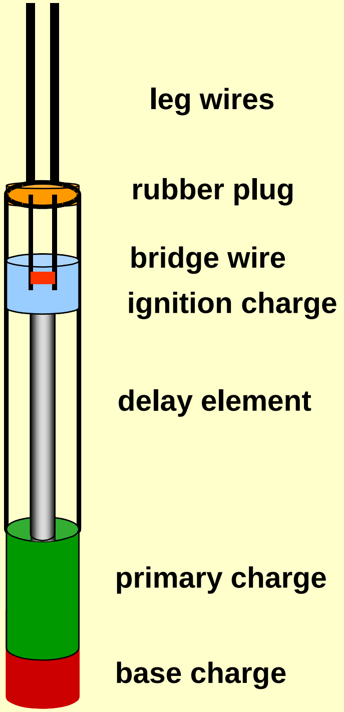
- Determine the type of blast, the number of detonators to be fired, the type of leg wires, the type of detonators, the length and gauge of the leading wire, and the connecting wires (if they are used);
- Calculate the equivalent number of 2.0-ohm copper-wire detonators that will be used in the blast, and determine the number of (1) balanced series and (2) detonators per series;
- Make certain the connecting wire in an individual series does not cause an imbalance in resistance that exceeds 10 percent;
- Calculate the resistance of the lead line and compare it to the acceptable limits; and
- Check the circuit with a blaster’s multimeter to determine the resistance.

Electric Systems

The blasting circuit in an electric-blasting system consists of electric detonators that are wired by connecting wires to the lead or firing line, which in turn is connected to the blasting machine.

Some of the components of an electric-blasting system are:

- An **electric detonator**, which is a metal shell containing a high-explosive base charge designed to initiate other explosives;
- **Leg wires**, which are insulated solid copper, iron, or copper-clad iron wires that protrude from electric detonators, allowing them to be connected to a blasting circuit;
- A **lead line**, which is an insulated copper wire (gauge 10 to 14) used to connect detonators to the blasting machine;
- **Connecting wires**, which are expendable insulated copper wires (gauge 16 to 20) used to connect (1) boreholes or (2) individual series to the lead line;
- A **blasting machine**, which is a capacitor-discharge machine capable of delivering the necessary current to detonate a series of electric detonators; and
- Some means to **test circuits** (a blaster's multimeter, a blasting ohmmeter, or a blasting galvanometer all can be used to test blasting circuits for continuity and resistance).



Electric Systems

In any blasting operation, the blasting machine should be directly under the control of the blaster in charge. It should be kept locked while not in use with the key in the blaster’s possession.

The lead (firing) line should not be laid out until the blast circuit is completely wired and all unnecessary personnel have been cleared to a safe location. After the lead line is laid out, it should be tested with a blaster’s multimeter for continuity.

Always inspect the lead line for cuts and abrasions to the insulation **BEFORE** every blast.

The lead line must be shunted at the blasting machine before connecting the other end to the blasting circuit. **NEVER** connect an unshunted lead line to the blasting circuit.

After the final connections have been made, the resistance of the entire circuit should be tested once again and the readings should match the calculated resistance. If proper readings are not obtained, reshunt the lead line before returning to the blast area to locate and correct the problem. **DO NOT** allow the bare ends of the circuit or the lead line to come in contact with the ground or with any metallic object.

Electric Systems

Testing Blasting Circuits

A blaster's multimeter, blasting ohmmeter, or blasting galvanometer can be used to test blasting circuits for continuity and resistance.

Individual detonators should be tested **before** making the primer and then again **before** stemming is placed in the borehole. Each circuit should be tested prior to hooking up the lead line. The circuit plus the lead line should be tested prior to firing the shot.

NEVER USE ANY TEST INSTRUMENTS NOT SPECIFICALLY DESIGNED FOR BLASTING CIRCUITS. The reason for this is that most standard electrician's AC-DC voltmeters and VAO meters are capable of supplying sufficient current to detonate an electric detonator; accordingly, they should **never** be used near blasting circuits.

Before using the test instrument, make certain the needle can be adjusted to "zero" when the terminals are shunted. Digital meters should read "zero" in the display. Replace the batteries with the same type of battery specified by the manufacturer for use in the blasting instrument. **NEVER** change batteries in the presence of electric detonators.

Electric Systems

Current and Extraneous Electricity

Sufficient current must be delivered within ms's, to a large number of detonators simultaneously, in order to successfully detonate the blasting circuit.

The accepted "safe" level of extraneous electricity for electrical blasting is derived from the current required to detonate the most sensitive commercial electric detonators plus a safety factor. The minimum firing current for electric detonators currently manufactured in the United States is approximately 0.25 amps.

The IME has established the maximum "safe" current permitted to flow through an electric detonator without hazard of initiation as one-fifth of the minimum firing current, or 0.05 amps, which provides a current safety factor of five.

ELECTRIC BLASTING MUST NOT BE CONDUCTED IN AREAS WHERE EXTRANEOUS CURRENTS GREATER THAN 0.05 AMPS EXIST.

Click on the image to the left to view a chart describing sources of extraneous electricity.

Review Questions and Discussion

1. When the switch on a blasting machine is thrown, the __ is closed, or completed, and the detonators wired to it __.
    a. Circuit; detonate
    b. Loop; misfire
    c. Shunt; are checked

2. In an electric detonator, the leg wires are connected to lead wires, which in turn are connected to an electrical blasting __.
    a. Tester
    b. Multimeter
    c. Machine

3. What instrument is used to measure resistance in a blasting circuit?
    a. Ohmmeter
    b. Battery charger
    c. Blaster's galvanometer
    d. Blaster's multimeter

4. Why aren't electric detonators used much at surface coal mines in Wyoming?
    a. Because of danger posed to them by overhead powerlines in the State
    b. Because of cellular-phone use in the State
    c. Because of lightening storms in the State
    d. Because of snow in the State

Review Questions and Discussion—continued

5. Lightning, static electricity, and radio-frequency energy are forms of __ that are very hazardous to any electric-blasting enterprise.
   a. Flyrock
   b. Extraneous electricity
   c. Airblast
   d. Blasting waves

6. True or false: a flashlight battery could detonate an electric blasting cap?

7. In an electrical-blasting system, primers are detonated by:
   a. Detonators set off by electrical charges
   b. Detonating cord
   c. Heat generated by the fuel oil or other chemical in the blasting agent
   d. All of the above

8. A single electric detonator may detonate when:
   a. No voltage flows through the wires
   b. A current of 0.25 amps flows through the wires
   c. The leg wires are joined
   d. b. and c. above

Answers

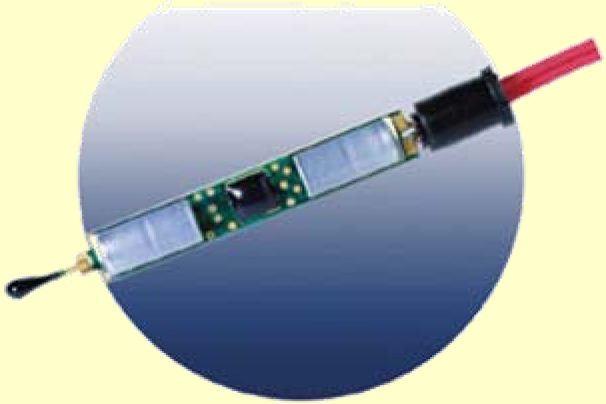
1. a. is correct.
2. c. is correct.
3. d. is correct.
4. a., c., and d. are correct.
5. b. is correct.
6. True.
7. a. is correct.
8. b. is correct.

Electronic Systems

Electronic-initiation systems are the latest trend in modern surface-mine blasting. These systems are numerous, and many of the larger explosive manufacturers have developed their own systems.

Unlike electric and non-electric systems, electronic blasting machines and accessories are designed specifically for each manufacturer.

Tie-in protocol and connectors are very specific to each manufacturer's system, and each user must become familiar with the specific detonators, operational limits, applications, and guidelines for his or her system.



Electronic Systems

Simple systems use factory-programmed electronic detonators that are initiated from shock tubes in the same way that ordinary shock tubes detonate. Each of these electronic detonators contains a piezoceramic device and a timing oscillator.

Some electronic systems are very complex and require custom blasting machines or computers to fire their detonators. Such detonators are field programmable and offer increased flexibility in operations that do a variety of blasting.

Electronic Systems

Blast-Management Capability

Electronic systems offer many computer-aided capabilities that are unavailable for electric and non-electric systems.

Electronic systems offer automatic safety checks for short circuits and non-connected firing lines, as well as systems checks for missing and extra detonators. They also map one-to-one among blasting plans stored in the blasting machine, and each detonator is checked online before firing.

Detonators can be programmed individually, or the entire blast plan can be programmed using a data card.

Security Level

The blasting machines used in electronic blasting systems will not activate unless the blaster unlocks the unit with either a key, a pass code, or both. Most electronic detonators are unable to be detonated with a conventional blasting machine.

Electronic Systems

Factory-Programmed Systems and Field-Programmed Systems

Factory-programmed systems have “fixed” delay periods, and holes to be shot with such systems are loaded in the same manner as are standard electric or shock-tube systems. Some manufacturers of factory-programmed systems include surface connectors for efficient tie-in or to maintain electrical polarity.

Field-programmed systems, on the other hand, are programmed on the bench. There are ***no fixed delay times*** associated with these detonators. In addition, most field-programmed systems have an electronic memory that allows them to be programmed either prior to loading or any time prior to firing by a direct communication between the blasting machine and the detonator.

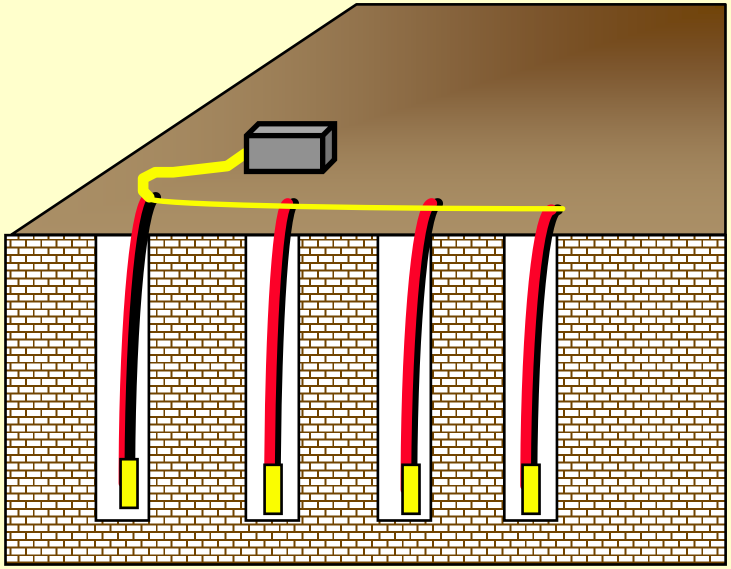
Click on the image above to play a clip showing the operation of a field-programmable detonator.

Electronic Systems

Factory-Programmed, Fixed Delay-Period Systems

A typical* factory-programmed, fixed delay-period electronic system features:

- Typically, two wires;
- Electric tie-in principles;
- Coded security;
- Multiple delay periods;
- A blast machine; and
- Sequential capability.



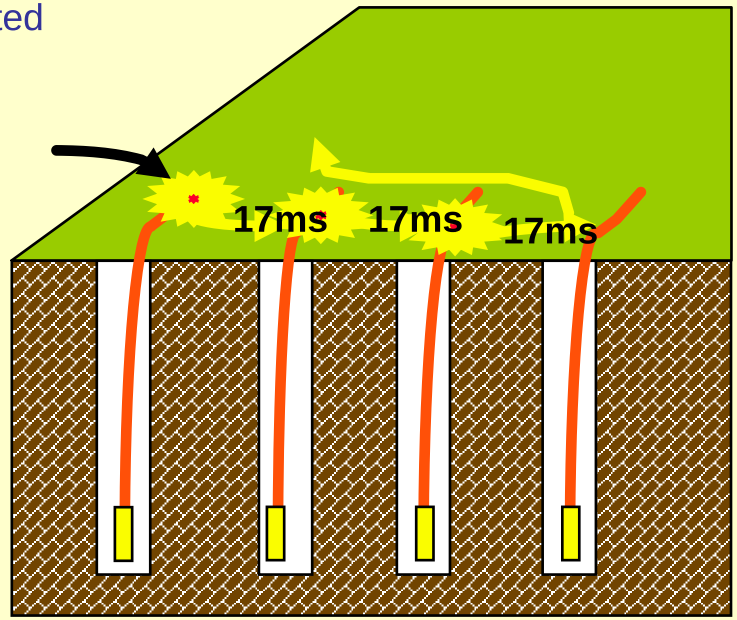
*As we have noted, there are several different electronic systems on the market today, and many of the larger explosive manufacturers have developed their own systems, each of them slightly different from the next. Hence, this and the descriptions on the following pages summarize only what might be considered a "typical" example of the subtype of system to which they pertain, not any system in particular.

Electronic Systems

Factory-Programmed, Shock-Tube-Initiated Systems

A typical factory-programmed, shock-tube-initiated electronic system features:

- Shock-tube leads;
- Energy transition;
- Electronic delay; and
- Standard tie-ins.

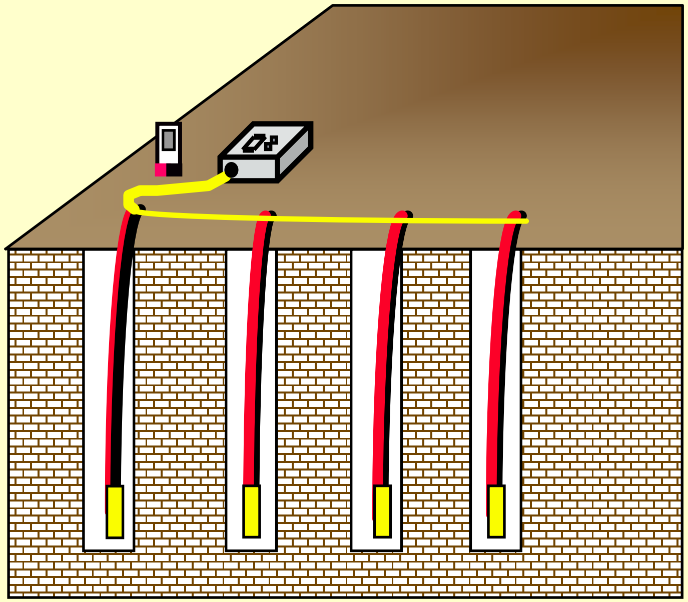


Electronic Systems

Field-Programmed, Variable-Delay-Period Systems

A typical field-programmed, variable-delay-period electronic system features:

- Two or more wires;
- Digital/coded security;
- 1-ms interval delays;



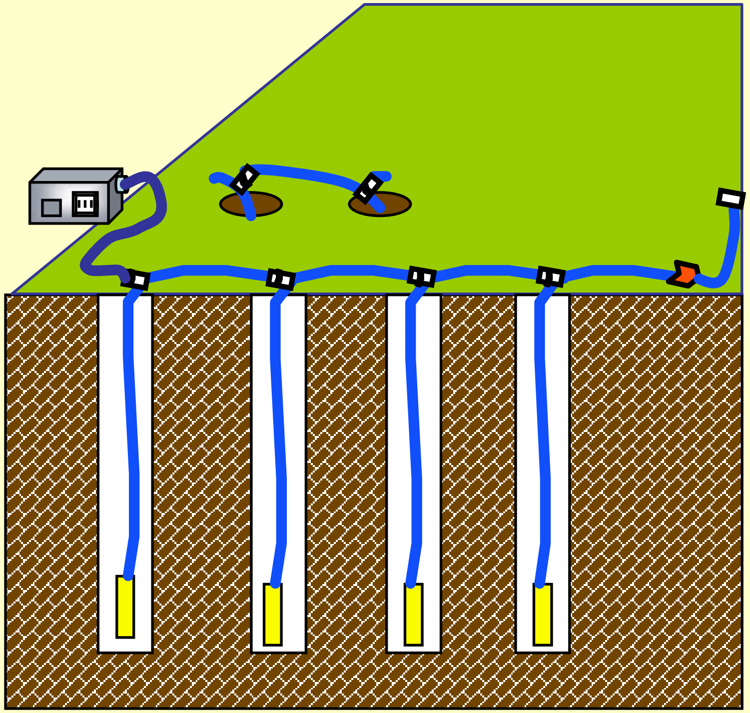
- Blast-machine programming;
- Hand-held programmers; and
- Blast-design software options.

Electronic Systems

In–Hole, Fixed-Delay-Interval Control Systems

A typical in-hole, fixed-delay-interval control system features:

- 5-wire ribbon wire;
- A blast machine and controllers;
- Series tie-in;
- Plug-in connectors;
- 32-second in-hole delay; and
- Pre-programmed surface controllers.

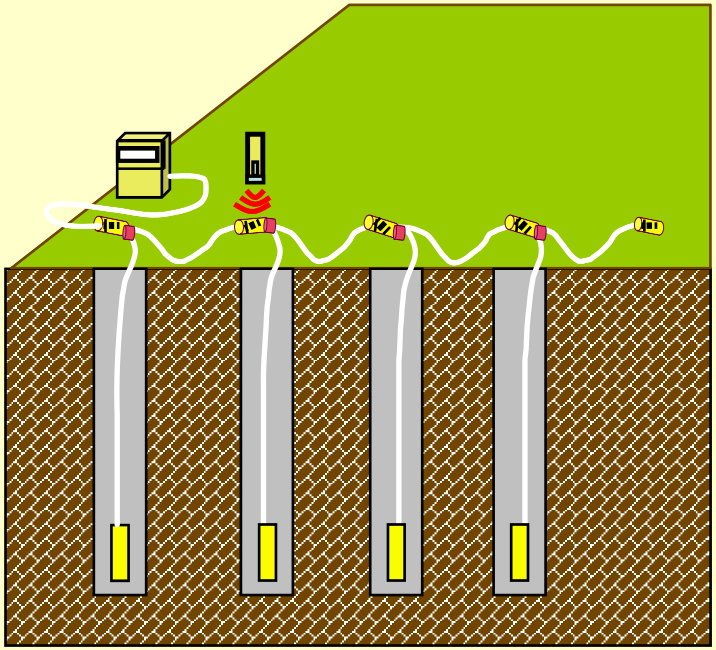


Electronic Systems

Passively Programmed, Field-Programmed Systems

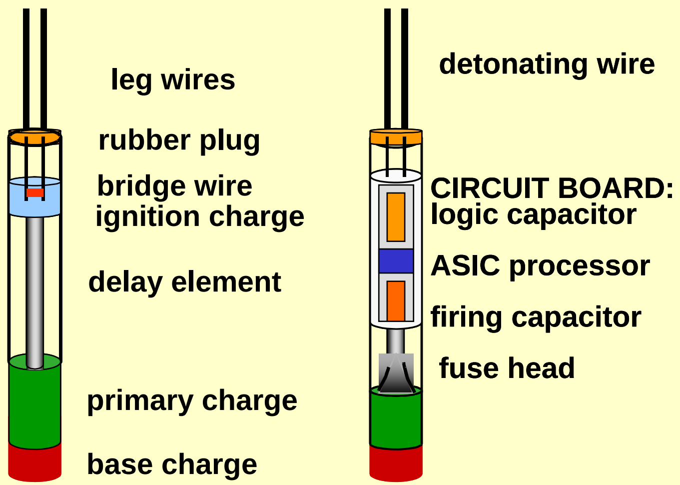
A typical passively programmed, field-programmed system features:

- Two wires;
- A blast machine, a computer, and scanners;
- Network tie-in;
- Plug-in connectors; and
- A bar-code reader that is sequenced and programmed.



Electronic Systems

Precise timing control is the main advantage of electronic detonators. Detonator firing errors are on the order of microseconds, as distinguished from the ms errors associated with pyrotechnic-delay detonators. Electronic detonators use circuit boards and programmable application-specific integrated circuit (ASIC) processors to add very precise delays that are more reliable than traditional pyrotechnic delays.



Electric detonator.

Electronic detonator.

Click the black screen above to see a test example of the accurate timing effects of electronic detonators, which, unlike 8-ms pyrotechnic delays, fire simultaneously.

Electronic Systems

IME “always” recommendations with respect to electronic detonation systems are:

- **ALWAYS** follow manufacturer’s warning and instructions, especially hook-up procedures and safety precautions;

- **ALWAYS** fire electronic detonators with the *equipment* and *procedures* recommended by the manufacturer;

- **ALWAYS** verify the integrity of the detonator system prior to initiation of a blast;

- **ALWAYS** follow the manufacturer’s instructions when aborting a blast (wait a minimum of 30 minutes before returning to a blastsite after aborting a blast, unless the manufacturer provides other specific instructions);

- **ALWAYS** keep detonator leads, coupling devices, and connectors protected until ready to test or fire the blast;

- **ALWAYS** keep wire ends, connectors, and fittings clean and free from dirt or contamination prior to connection;

- **ALWAYS** follow manufacturer’s recommended practices to protect electronic detonators from electromagnetic, radio-frequency, or other electrical interference sources;

- **ALWAYS** protect electronic detonator wires, connectors, coupling devices, and shock-tube or other components from mechanical abuse and damage;

- **ALWAYS** ensure that the blaster in charge has control over the blastsite throughout the programming, system charging, firing, and detonation of the blast; and

- **ALWAYS** use extreme care when programming delay times in the field, to ensure correct blast designs; incorrect programming can result in misfires, flyrock, excessive airblast, and vibration.

Electronic Systems

Likewise, IME "never" recommendations with respect to electronic detonation systems are:

- **NEVER** *mix electronic* detonators and *electric* detonators in the same blast, even if they are made by the same manufacturer, unless such use is approved by the manufacturer;

- **NEVER** *mix* electronic detonators of *different types and/or versions* in the same blast, even if they are made by the same manufacturer, unless such use is approved by the manufacturer;

- **NEVER** *mix* or use electronic detonators and equipment made by *different manufacturers*;

- **NEVER** use test equipment and blasting machines designed for electric detonators with electronic detonators;

- **NEVER** use equipment or electronic detonators that appear to be damaged or poorly maintained; and

- **NEVER** attempt to use blasting machines, testers, or instruments with electronic detonators that are not specifically designed for the particular electronic-detonation system you are using.

Electronic Systems

In addition, IME recommends that you:

- **NEVER** attempt to cut and splice leads unless specifically recommended by the manufacturer;

- **NEVER** make final hook-up to the firing device or blast controller until all personnel are clear of the blast area;

- **NEVER** load boreholes in open work areas near electric powerlines unless the firing lines and detonator wires are anchored or are too short to reach the powerlines;

- **NEVER** handle or use electronic detonators during the approach and progress of an electrical storm (personnel must be withdrawn from the blast area to a safe location under such conditions);

- **NEVER** use electronic detonator systems outside the manufacturer's specified operational temperature and pressure ranges;

- **NEVER** test or program an electronic detonator in a booster, cartridge, or other explosive component (primer assembly) before it has been deployed in the borehole or otherwise loaded for final use; and

- **NEVER** hold an electronic detonator while it is being tested or programmed.

Click the image above to play a video clip showing an electronic-detonation system in use.

Review Questions and Discussion

1. Some electronic blasting systems are very complex and require either custom blasting machines or __ to fire their detonators.
    a. CD blasting machines
    b. Guns
    c. Loggers
    d. Computers

2. Factory-programmed detonators are available for some electronic blasting systems, whereas other systems use smart detonators that can be programmed on the:
    a. Shelf
    b. Bench
    c. Truck
    d. All of the above

3. True or false: field-programmed detonators usually have fixed delay times?

4. Pyrotechnic delays typically show timing ranges of ± 5 milliseconds. Electronic-delay timing ranges have been tested to ± 1:
    a. Nanosecond
    b. Millisecond
    c. Macrosecond
    d. Microsecond

5. True or false: incorrect detonator programming can result in misfires, flyrock, excessive airblast, and vibration?

Answers

1. d. is correct.
2. b. is correct.
3. False.
4. d. is correct.
5. True.

Cap-and-Fuse Systems

A **cap-and-fuse system**, also called a fuse-detonator system, consists of blasting caps and fuse detonators that are crimped to a length of safety fuse.

In a safety-fuse system, the fuse is typically ignited with either a hot-wire fuse lighter, a pull-wire fuse lighter, or an igniter cord and igniter-cord connectors.

Cap-and-fuse systems should be used only by supervised, trained, experienced, and skilled blasters who are completely familiar with the use of explosives on a day-to-day basis.

In addition, cap-and-fuse blasting should only be used where a long delay time between the detonating of individual holes will not create a problem.

Cap-and-Fuse Systems

A **safety fuse** is a medium through which flame is continuously conveyed at a relatively uniform speed to initiate the heat-sensitive charge in an ordinary blasting cap. Cap-and-fuse assemblies are able to fire single charges or multiple charges designed to initiate in rotation.

Charges that must be shot instantaneously, as in pre-shear (perimeter control, presplitting, etc.) work, or those that require short delay intervals cannot use a safety-fuse initiation method, because blast timing with a fuse is not sufficiently precise.

IME recommendations with respect to cap-and-fuse detonation systems are:

- **ALWAYS** handle a fuse carefully to avoid damaging the covering;

- In cold weather, **ALWAYS** warm the fuse slightly before using it, to avoid cracking the waterproofing;

- **ALWAYS** know the burning speed of a safety fuse (burning speed can be determined by conducting a test burn of the fuse in use, to make sure you have time to reach safety after lighting it);

- **NEVER** use lengths of safety fuse less than 3 feet; and

- **NEVER** insert anything but a fuse into the open end of a detonator.

Cap-and-Fuse Systems

In addition, IME recommends that you:

- **ALWAYS** cut 1 or 2 inches off a fuse, to ensure a dry end (cut the fuse squarely across with the proper tool designed for this purpose; ***DO NOT*** use a knife);

- **ALWAYS** seat the fuse lightly against the detonator charge and avoid twisting after it is in place;

- **ALWAYS** ensure that the detonator is securely crimped to the fuse;

- **ALWAYS** use a waterproof crimp or waterproof the fuse-to-detonator joint in wet work;

- **ALWAYS** use cap crimpers to crimp the detonator to the safety fuse;

- **NEVER** twist the fuse inside the detonator;

- **NEVER** use a knife or teeth for crimping;

- **NEVER** use an open-fuse detonator for a booster;

- **NEVER** cut a fuse until you are ready to insert it into the detonator;

- **NEVER** crimp detonators by any means except a cap crimper designed for the purpose; and

- **NEVER** attempt to remove a detonator from the fuse to which it is crimped.

Cap-and-Fuse Systems

The steps for assembling a fuse detonator and a safety fuse are:

Step 1.—Wait until you are ready to insert the fuse into the fuse detonator before cutting it.

Step 2.—Cut off 1 or 2 inches of the fuse to ensure a dry end.

Step 3.—Measure the correct length of the fuse from the roll, and cut squarely across with a fuse cutter designed for this purpose. Do not use a knife.

Step 4.—Visually inspect the inside of the detonator for foreign material or moisture; if the detonator is wet or if foreign matter cannot be removed by pouring, do not use the detonator. Instead, dispose of it in an approved manner.

Step 5.—Put the safety fuse gently against the powder charge.

Step 6.—Crimp the end of the fuse detonator where the fuse enters, using a cap crimper.

Cap-and-Fuse Systems

The crimp is an indentation on the cap shell that joins the cap and fuse together. Crimps should be tight enough both to hold the cap securely in place and to provide a watertight seal. If the crimp is loose, the fuse may pull away from the cap charge or out of the cap, allowing moisture to come in contact with the ignition powder.

All crimps must be made near—**not more than 3/8 inch (9.5 millimeters) from**—the open end of a cap shell. Crimping more than 3/8 inch (9.5 millimeters) from the open end of the shell can prematurely initiate the cap.

NEVER ATTEMPT TO CRIMP THE CAP WITH THE FUSE CUTTER, AS THE CAP MAY DETONATE.

Cap-and-Fuse Systems

Recommended steps for lighting a safety fuse are:

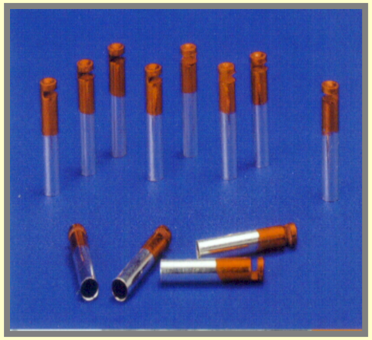
Step 1.—Make sure you can reach a safe location after lighting, with sufficient time before initiation.

Step 2.—Place sufficient stemming over the explosive material to protect it from fuse-generated heat and sparks.

Step 3.—Have a partner before lighting the fuse. One person should light the fuse, and the other should time and monitor the burn.

Step 4.—Light the safety fuse using a specially designed lighter: a single-fuse ignition requires a hot-wire lighter, a pull-wire lighter, or thermalite connectors; a multiple-fuse ignition requires an igniter cord with thermalite connectors.

Igniter cord.



Igniter-cord connectors.

Cap-and-Fuse Systems

With respect to cap-and-fuse systems, remember that:

- **The fuse burns at its core, not at its cover;**
- **You should have two persons present when lighting the fuse;**
- **The explosive charge must in place before the fuse is lit; and**
- **If the charge does not detonate or you do not hear the detonation at the calculated time, you should not return to the blast area for at least 1 hour.**

Review Questions and Discussion

1. __ is a permissible means of lighting a safety fuse.
    a. A cigarette lighter
    b. A hot-wire lighter
    c. Matches
    d. All of the above

2. When a safety fuse or blasting caps appear to have misfired, persons shall not enter the blast area for __ minutes.
    a. 20
    b. 30
    c. 45
    d. 60

3. Which of the following are sources of extraneous electricity?
    a. Lightning storms
    b. Stray AC current
    c. Radio frequency
    d. All of the above
    e. None of the above

Review Questions and Discussion—continued

4. Why would you choose a shock tube over a detonating cord to detonate your blast?
    a. Airblast concerns
    b. Storage concerns
    c. The desire for greater control over timing
    d. All of the above

5. In locations that are close to residential or commercial sites, the noise that a detonating-cord trunkline generates during a blast may cause complaints. Which, if any, of the following approaches might be used to address this prospective problem?
    a. Eliminate the trunkline by replacing it with either an electric, a flash-tube, or an electronic detonator
    b. Initiate a detonating cord upline, from the bottom of the hole, using either an electric or a non-electric detonator
    c. Cover the trunkline with at least 12 inches of fine drill cuttings or dirt
    d. Any of the above
    e. None of the above

Answers

1. b. is correct.
2. d. is correct.
3. d. is correct.
4. d. is correct.
5. a. is correct.