STUDY GUIDE

FOR THE

GENERAL BLASTERS EXAMINATION

COMMONWEALTH OF KENTUCKY

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Division of Mine Reclamation and Enforcement
Explosives and Blasting Branch

Kentucky
UNBRIDLED SPIRIT

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FOREWORD

The following study guide has been compiled for the benefit of those persons planning to take the Kentucky blaster's licensing examination. While we recommend that applicants for a blaster's license attend one of the department's training courses before attempting the exam, we realize that due to our limited resources, the classes may not be available at a convenient time or location for everyone. To alleviate some problems, we offer this booklet as a study aid.

The general blaster's licensing examination is a thorough examination covering all aspects of blasting. Approximately 40% of the test is related to the laws and regulations governing storage, transportation, and the use of explosives. Another 40% of the test is devoted to methods of blasting, terminology, and other general information that a blaster would be expected to know. The remaining portion of the exam covers some basic mathematical calculations with which a blaster should be familiar.

In addition to the material covered in this booklet, it is important that you familiarize yourself with the "Laws and Regulations Governing Explosives and Blasting" which is published under a separate cover by the Division of Mine Reclamation and Enforcement, Explosives and Blasting Branch. Also, since study of *IME'S WARNINGS AND INSTRUCTIONS*, which are guidelines concerning the safe use of explosives is highly recommended, we have reprinted them in this booklet with permission of the Institute of Makers of Explosives.

Please keep in mind that in addition to passing the examination, there is a requirement to obtain a license that a person must have "worked in blasting operations for at least twenty four (24) months under the supervision of on experienced blaster." Two departmental affidavits must verify this experience.

Martin Brashear, Manager
Explosives and Blasting Branch

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DEFINITIONS

AIRBLAST - the noise and concussion originating from a blast usually produced by the detonation gases venting to the atmosphere. Airblast can be severe when explosives are detonated unconfined.

ANFO - is a mixture composed of 94% ammonium nitrate and 6% fuel oil by weight. The ammonium nitrate is normally in the form of a porous prill, which absorbs the fuel oil when mixed. It is the most widely used blasting agent because it is economical, and relatively safe due to its low sensitivity. The major disadvantage to ANFO is its lack of water resistance.

ARCING - is a malfunction of an electric blasting cap caused by applying an excessive amount of firing current for too long a time. This can result in either a misfire or a hangfire.

TWO COMPONENT EXPLOSIVE - also called BINARY explosives - an explosive made up of 2 non-explosive materials, which when combined form a high explosive. Prior to mixing, the materials need not be stored, transported or handled as explosives. Once mixed they become high explosives and must be treated as such.

BACKBREAK - (sometimes called OVERBREAK) cracks, fissures, or complete rock breakage that extends behind the last row of boreholes that detonated.

BLASTING AGENT - any material or mixture, consisting of a fuel and oxidizer used for blasting, but not classified as an explosive. The determining factor in classifying a material as a blasting agent rather than a high explosive is the fact that a blasting agent is not cap sensitive.

BLASTING MACHINE - a instrument designed expressly for the purpose of initiating electric blasting caps. A blasting machine can be a "condenser-discharge" type in which an internal battery charges a capacitor(s) and the capacitor then discharges its energy through the cap circuit when the machine is fired. Other blasting machines can be generator types, in which the action of the person pushing or twisting a handle creates a current sufficient to fire a number of electric blasting caps.

BLOCKHOLE - a hole drilled into a boulder to allow the placement of a small charge in order to break the boulder as a means of secondary blasting.

BOOSTER - a high explosive cartridge, not containing an initiating device, loaded in a powder column used for intensifying the detonation. Such use of boosters is commonly accepted to be inefficient and uneconomical.

BOOTLEG - bottom portion of a borehole which remains intact after loading with explosives and detonated. May contain undetonated explosives and should be examined carefully.

BRIDGING - a break in the continuity of a column of explosives in a borehole caused by improper placement of the charges, or foreign matter separating the charge column.

BULK EXPLOSIVES - explosive materials which are not packaged but rather delivered directly from a truck or bin.

BURDEN - generally considered the distance from an explosive charge to the nearest free or open face. Technically, there may be an apparent burden and a true burden, the latter being measured always in the direction in which displacement of broken rock will occur following firing of an explosive charge.

CARTRIDGE - a rigid or semi-rigid cylindrical shaped package of explosives.

CAST BLASTING - the use of explosives to not only break the rock but also to displace or move it in a beneficial direction or intended location. It is most often used in surface coal operations to uncover the coal seam.

COLLAR - the opening at the surface or top of a borehole.

CURRENT LEAKAGE - the loss of some or all of the firing current when it is applied to a cap circuit.

CUSHION BLASTING - the technique of firing a single row of hole along a neat excavation lie to shear the web between the closely drilled holes; This type of controlled blasting is fired after production shooting has been completed and the material removed.

CUTOFFS - a portion of a borehole which fails to detonate due to bridging or shifting of rock strata. It also refers to the incomplete detonation of a blast pattern which may occur when the initiating system is cut or broken.

CYCLING - the ability of a material such an ANFO to change its crystal structure as the temperature changes. ANFO cycles at temperatures of approximately 0° and 90° which causes the prills to deteriorate and lose their protective coating.

DECK - to load a borehole with two or more charges, each with their own detonator, and separated from each other by stemming material. That portion of a borehole loaded with explosives that is separated from other charges in the same borehole is also called a deck.

DEFLAGRATION - an explosive reaction that consist of burning at a high rate of speed resulting in large gas formation and pressure expansion.

DELAY INTERVAL - time between the detonation of individual charges; by law must be a least 8 milliseconds.

DENSITY - the weight or mass per unit volume of a material. (i.e. grams/cc, lb/ft^3). The density of explosive materials are often measured in terms of specific gravity.

DETONATION - an explosive reaction that consists of the propagation of a shock wave through the explosive accompanied by a chemical reaction that furnishes energy to sustain the shockwave propagation in a stable manner, with gaseous formation and pressure expansion following shortly thereafter.

DETONATING CORD - a flexible cord containing a core of high explosives which, when detonated, has sufficient strength to detonate high explosives with which it is in contact.

DETONATORS - blasting caps, electric blasting caps, delay electric blasting caps, non-electric delay blasting caps and electronic blasting caps.

DOWNLINE - a length of detonating cord extending from the surface into the borehole and attached to or in contact with the explosives or primer.

DUPLEX WIRE - two separate insulated electric conductors enclosed in a single sleeve.

ELECTRIC BLASTING CIRCUITRY
A. Bus Wire - solid wire, used in parallel or series circuits, to which are connected the legwires of electric blasting caps. Not to be reused.
B. Connecting Wire - an insulated solid wire used between electric blasting caps and the leading wires or between the bus wire and leading wires. Not to be reused.
C. Leading Wire also called lead wire or firing cable- an insulated solid wire used between the electric power source and the electric blasting cap circuit.

EXTRANEOUS ELECTRICITY - any electrical energy that could get into an initiating device, other than the small test current from a blasting ohm meter or the firing current in an electric blasting circuit (i.e. stray current, static electricity, lightning, current induced by radio frequency energy or high voltage power lines).

FRAGMENTATION - the degree to which rock is broken by the blast.

FREE FACE - rock surface which is uncovered or open and provides space for the expansion and movement of blasted rock when detonation occurs.

FUME CHARACTERISTIC - measure of the amount of toxic gases produced by a detonation of an explosive. The U. S. Bureau of Mines fume classes (A or B) are based on the cubic feet of poisonous gases produced by a 1 1/4" x 8" cartridge. The Institute of Makers of Explosives also classify explosives as class 1,2,3 or unclassified based upon the amount of toxic gases produced by detonation of 200 grams of explosive.

FUMES - in blasting the toxic oxides of nitrogen or any other poisonous gas produced by a detonation.

FUSE LIGHTERS - special devices for the purpose of igniting safety fuse.

GALVANOMETER - an electronic instrument designed expressly for the purpose of measuring resistance and checking continuity in an electrical blasting circuit.

GRADE LINE - the depth to which an excavation is planned. In order to break the rock to the grade line normally requires sub-drilling

GROUND VIBRATION - a wave transmitted through the ground, similar to an earthquake, that causes the particles of ground to oscillate as it passes.

HANG FIRE - the partial or total burning of a charge that may eventually result in an explosion.

HIGH EXPLOSIVES - an compound or mixture that will detonate and can be initiated with a blasting cap.

LIFT SHOT - a blast which is confined on all sides with no free face to provide relief, movement of the rock when detonated is vertical.

LOADING FACTOR - weight of explosive loaded per foot of blast hole depth

LOW EXPLOSIVES - mixture or compound which will deflagrate when initiated, that is they produce the high temperature and pressure gas but without the shock wave.

MAGAZINE - any building or structure, used for the storage of explosives

MAT - used to cover a shot to hold down flying materials; usually made of wire cable, rope or old tires cut and woven together.

MILLISECOND - 1/1000th of a second

MISFIRE - a charge, or part of a charge which fails to detonate as planned.

MUD-CAPPING - the breaking of boulders by placing a quantity of explosives against a rock, boulder, or other object without confining the explosives in a drill hole.

MUD SEAM - a layer of mud, dirt, or loose gravel that is embedded in between harder rock strata. Mud seams may not be detected visually but should be obvious if drilled into or through.

MULTIPLE PRIMING - two or more cartridges containing detonators placed in the same borehole.

NONEL - non-electric method of blasting using a shock tube to convey the firing signal to the detonators.

OVERBURDEN - in construction blasting, the material lying on top of the rock to be shot, in mining, the waste rock overlying the materials being mined. (eg. the sandstone overlying a coal seam)

PATTERN - a plan of boreholes as laid out on a bench, usually expressed in terms of feet of burden and spacing.

PERMISSIBLE - explosives having been approved by the U. S. Bureau of Mines for use of gassy underground mines. The factors determining permissibility is the volume, the temperature, and duration of flames produced during detonation.

POWDER - explosives, usually referring to cartridged high explosive

POWDER COLUMN - OR COLUMN CHARGE - a continuous length of explosives loaded into the borehole.

POWDER FACTOR - the ratio of the weight of explosive to amount of rock broken.

PRE-BLASTING SURVEY - an inspection and documentation of the condition of a structure prior to blasting occurring in the vicinity.

PRE-SPLITTING - procedure using a single row of holes drilled along the excavation boundary, which are loaded lightly with explosives and fired prior to the production blasts. This produces a shear line along the edge of the excavation and forms a competent and neat final wall when excavated.

PRILL - small porous pellet of ammonium nitrate.

PRIMARY BLASTING - the blasting operation by which the original rock formation is dislodged form its natural locations.

PRIMER - a cartridge or container of explosives into which a detonator or detonating cord is inserted or attached. It is used to initiate the charge in which it is placed.

PROPAGATION - the detonation of a charge by shock or pressure form an adjacent explosion.

ROUND - a group of blast holes to be fired as a single blast.

SAFETY FUSE - a flexible cord containing an internal burning medium by which fire is conveyed at a continuous and uniform rate for the purpose of firing blasting caps.

SCALE DISTANCE - the ratio of the actual distance between the blast site and a dwelling to the square root of the weight of explosive per delay period.

SECONDARY BLASTING - the reduction of over size material by the use of explosives to a size required for handling; usually accomplished by mudcapping and blockholing.

SEISMOGRAPH - an instrument that measures and supplies a permanent record of earthborne vibrations induced by earthquakes, blasting, etc.

SENSITIVENESS - a measure of the propagating ability of an explosive.

SENSITIVITY - a measure of how easy an explosive can be initiated. There are various types of sensitivity such as: cap sensitivity, impact sensitivity, bullet sensitivity.

SEQUENTIAL BLASTING MACHINE - a machine for supplying electrical energy to a number of separate cap circuits at precise time intervals. Use of the delays between circuits enables a blaster to increase the number of delay intervals available.

SHUNT - a piece of metal connecting two ends of legwires to prevent stray currents from causing accidental detonation of the cap. The act of deliberately shorting any portion of an electrical blasting circuit.

SIMPLEX WIRE - single electric conductor enclosed in an insulating sleeve.

SLURRY OR WATER GELS - explosives containing substantial proportions of water and high proportions of ammonium nitrate, some of which is in solution in the water. May be a high explosive or a blasting agent depending on the sensitizing material used. Can be loaded in bulk or in plastic tube type cartridges.

SPACING - distance between boreholes in a row measured perpendicular to the burden and parallel to the free face.

SPECIFIC GRAVITY - the ratio of the density of a material to the density of water. (eg. specific gravity of free-flowing ANFO is approximately equal to 0.8). Specific gravities less than 1.0 are lighter than water; specific gravities greater than 1.0 are heavier than water.

STEMMING - a suitable inert, incombustible material used to confine or separate explosives in a drill hole. Crushed stone, dirt, or material from the drill are commonly used as stemming material.

STICK COUNT - is a method of designating an explosive's density. it is equal to the number of 1 1/4 x 8 inch cartridges contained in a 50 pound case of the particular explosive.

STRENGTH - a measure of the energy content of an explosive in relation to nitroglycerine dynamite. (eg. 40% nitroglycerine dynamite - 40% of its weight is actually nitroglycerine; 40% gelatin has an equivalent energy to 40% dynamite).

SUB-DRILL - to drill blastholes deeper than the planned excavation line.

TAMPING - the process of compacting the stemming or explosive in a blasthole.

TENSILE STRENGTH - the maximum amount of force that can be exerted on a cord or tube without breaking it.

TOE - distance between the borehole and the vertical free face of a bench measured at the bottom of the bench. (Also sometimes refers to a bootleg).

TRUNKLINE - a length of detonating cord on the surface connecting the downlines from each of the boreholes together.

VELOCITY OF DETONATION - the speed at which the detonation travels through the explosive column. Ranges from 6000 ft/sec to 24000 ft/sec based upon the type of explosive and borehole diameter.

WATER RESISTANCE - the ability of an explosive to be exposed to water and not deteriorate or lose efficiency.

ELECTRIC BLASTING

One tool that all blasters should be familiar with is the blasting galvanometer. A blasting galvanometer is a special type of electronic instrument with an "ohms" scale which measures the electrical resistance of a blasting circuit. It is special or unique because it operates with an such a very small current that it cannot accidentally detonate any electric blasting caps in the circuit. Accidents and fatalities have occurred when regular ohmmeters or electrician's voltmeters have been used to test blasting circuits. ***For your safety and that of everyone on the blasting crew it is imperative that only a "Blaster's Galvanometer, or Blaster's Multimeter" be used to test blasting circuits.***

When blasting electrically, it is essential that all circuits be checked for continuity before attempting to fire them. Additionally, if is often useful to calculate the resistance of a firing circuit and to compare this calculated resistance with the actual reading measured with the blasting galvanometer. Any significant difference between the two indicates a potential problem such as shorted wires, loose connection, or even a mistake in wiring.

A galvanometer reading which is higher than the calculated value of resistance may be caused by dirty or loose connections which increase resistance. A reading of zero ohms (the needle deflects full scale) indicates a short circuit. A reading of less resistance than calculated may indicate a number of caps not wired into the circuit or a partial short circuit. If the needle does not move at all when the wires are touched to the terminals, this would indicate a break in the circuit (i.e. open circuit, and no current will flow).

The total resistance of a blasting circuit is made up of the resistance of the caps, the resistance of any connecting wire used, and the resistance of the firing line or lead line. In most series circuits, the contribution of the lead line resistance and the connecting wire resistance is very small compared to the resistance of the caps. However, in large series parallel circuits the resistance of the connecting wire and the firing line becomes noticeable. The greater the number of parallel branches contained in a circuit, the more significant the resistance of the wires become. In a pure parallel connection, the resistance of the lead line will overshadow any resistance from the caps.

Calculating Resistance in a Single Series

The most basic type of blasting circuit is the single series. A series circuit is one in which there is only one path or loop for the firing current to travel. There are certain characteristics associated with a series circuit. These are as follows:

1. A break or failure in any part of a series circuit will prevent current from flowing in the entire circuit.
2. All blasting caps in a series receive the same amount of current.
3. The total resistance of a series circuit is the sum total of the individual resistances

These qualities of series circuit lead to several advantages and at least one disadvantage to its use as a firing circuit for blasting caps. Since all caps receive the same amount of current, the possibility of partial misfires due to uneven distribution of current is unlikely. Likewise continuity and total circuit resistance are easy to measure and compare to predictions. Unfortunately, since the resistance of the circuit is proportional to the number of caps, there is an upper limit on the number of caps and the resistance that can be wired into a circuit which is determined by the capacity of the blasting machine that is used.

The following are examples of a series wiring:

In order to calculate the resistance of a number of caps wired in series, use the formula: $R_T = R_1 + R_2 + R_3 + R_4$....,

where R_1, R_2, R_3, etc, are the resistances of individual caps, and R_T is the total resistance of the circuit.

Electrical resistance is measured in terms of "ohms". The more ohms of resistance that a circuit has, the more opposition to the flow of current it presents. A typical electric blasting caps will have a resistance between 1 ohm and 3 ohms. The factors which determine the resistance of a cap are (1) the length of the legwires, (2) the gauge or thickness of the leg wires, and (3) whether the wires are copper or iron. From the following table we can generalize and say that the longer the leg wires, the higher the resistance of the cap; also it is obvious that caps with iron leg wires have greater resistance than caps with copper leg wires.

TABLE A

Nominal Resistance of EB Caps

Resistance in ohms per cap

Legwire Length	Copper Legwires	Iron Legwires
6 ft	1.6 ohms	2.8 ohms
8 "	1.7 "	3.3 "
10 "	1.8 "	3.8 "
12 "	1.8 "	4.3 "
16 "	1.9 "	5.3 "
20 "	2.1 "	6.3 "
24 "	2.3 "	7.3 "
28 "	2.4 "	8.3 "
30 "	2.1 "	8.8 "
40 "	2.3 "	11.3 "
50 "	2.6 "	13.8 "
60 "	2.8 "	16.4 "
80 "	3.3 "	21.4 "
100 "	3.8 "	26.4 "
120 "	4.4 "	
150 "	5.1 "	
200 "	6.4 "	

This table is for use as an example only; the resistance of caps from different manufacturers will vary. Check with the manufacturer to obtain a chart or table of the resistances for their particular brand of cap.

Problem 1: A small blasting circuit, consisting of 5 caps, is wired as a single series. If each cap has a resistance of 2.3 ohms, what is the total resistance of the circuit?

Solution: Total Resistance $= R_1 + R_2 + R_3 + R_4 + R_5$
$= 2.3 + 2.3 + 2.3 + 2.3 + 2.3$
$= 5 \times 2.3$
$= 11.5$ ohms

Problem 2: What will the resistance of 20 caps in series be if they have copper legwires 12 feet long?
Solution: (Use Table A to find resistance of one cap)

Total Resistance $= R_1 + R_2 + \ldots\ldots + R_{20}$
$= 1.8 + 1.8 + \ldots\ldots + 1.8$
$= 20 \times 1.8$
$= 36$ ohms

Problem 3: A circuit consists of a 16 foot cap, a 20 foot cap, a 24 foot cap. and a 28 foot cap, all connected in a single series. If these caps have iron legwires, what is the total resistance of the circuit?

Solution: Total Resistance $= R_1 + R_2 + R_3 + R_4$

$= 5.3 + 6.3 + 7.3 + 8.3$

$= 27.2$ ohms

Problem 4: A blasting circuit has twenty-five caps connected in series. If each cap has a resistance of 2.1 ohms, what is the resistance of the circuit?

Solution:

Problem 5: Fourteen Caps, having 10 foot iron legwires are connected in a single series. What is the total resistance of the circuit?

Solution:

Problem 6: A blasting circuit has the following caps with copper legwires connected in single series:

Twelve caps with 20 foot legwires
Twelve caps with 30 foot legwires
Twelve caps with 40 foot legwires
Four caps with 50 foot legwires

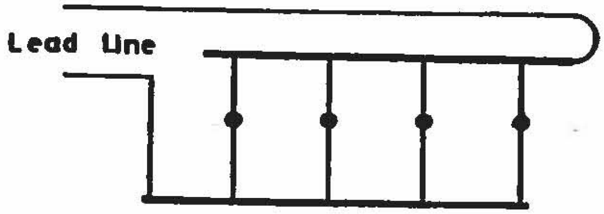
What is the resistance of this circuit?

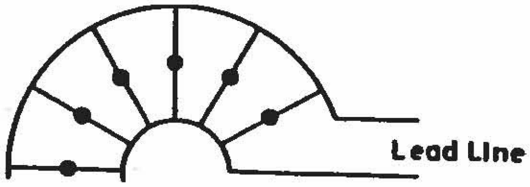
Solution:

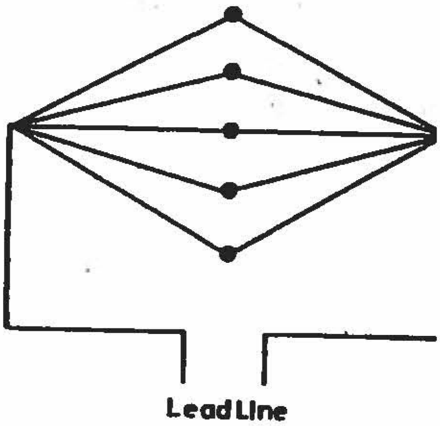
Calculating Resistance in a Parallel Circuit

Another basic type of electrical circuit is the parallel circuit. In a pure parallel circuit, all components (electric blasting caps) are connected across two common points or between two common conductors. Each component then provides a separate conducting path for the current.

Typical parallel connections would be:







In a parallel circuit, a break in one branch will *not* prevent current from flowing in the other branches. A pure parallel circuit is seldom used in surface blasting; though it is sometimes used in tunnel and shaft excavations because of the ease of hook-up.

Some disadvantages to the use of a pure parallel connection are: (1) It is extremely difficult to check for continuity in all branches after they have been wired together. (2) Very high current is required from the power source, and (3) If the resistances in the parallel branches are unbalanced, they will receive a different amount of current leading to the possibility of misfires.

The formula for calculating resistance in parallel is:

$$\frac{1}{\text{Total Resistance}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots\ldots\ldots\ldots$$

Problem 7: Six electric blasting caps having 20 foot copper legwires are connected in parallel. What is the total resistance of the circuit? Use Table A.

Solution:

$$\frac{1}{\text{Total Resistance}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots\ldots\ldots\ldots$$

$$\frac{1}{\text{Total Resistance}} = \frac{1}{2.1} + \frac{1}{2.1} + \frac{1}{2.1} + \frac{1}{2.1} + \frac{1}{2.1} + \frac{1}{2.1}$$

$$\frac{1}{\text{Total Resistance}} = \frac{6}{2.1}$$

$$\text{Inverting, Total Resistance} = \frac{2.1}{6} = .35 \text{ ohms}$$

From this solution you may notice that the total resistance of the circuit is equal to the resistance of an individual cap (2.1) divided by the number of caps in parallel (6). This short-cut method will work in all cases where the resistances in each branch are identical. Since even current distribution requires that the resistance in each branch be balanced, (equal in each branch), this method should work in the majority of problems.

Problem 8: Ten caps, each having 3.8 ohms resistance, are connected in parallel. What is the total resistance of the circuit?

Solution:

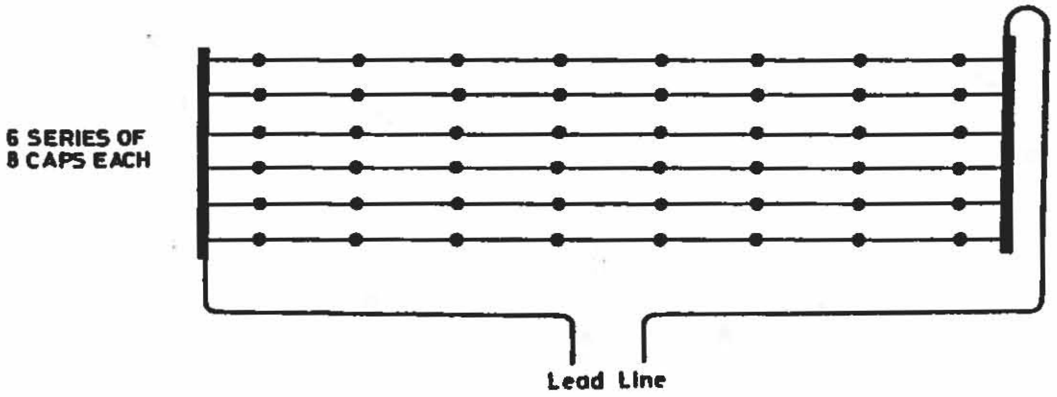
Problem 9: A parallel blasting circuit has twenty caps each having 30 foot copper legwires. What is the total resistance?

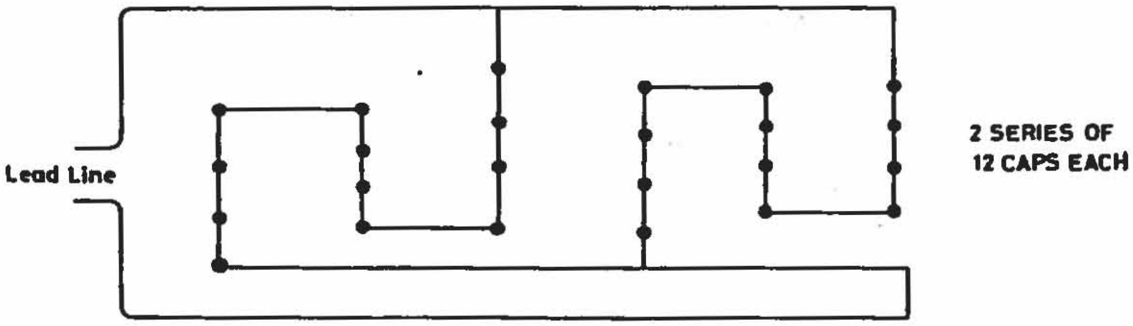
Solution:

Calculating Resistance in Series-Parallel

All blasting machines have an upper limit on the number of caps that can be fired in a single series. When a shot requires that more caps be detonated, it is necessary to divide the total number of caps into two or more series. These series can then be wired in parallel to each other. This method decreases the total resistance of the circuit, and increases the total number of caps that a blasting machine can detonate within its capacity.

Examples of a series-parallel circuit are:





To calculate the resistance in a series-parallel requires two separate operations. First, the resistance of each individual series is found in exactly the same way that the resistance of a single series was previously calculated. Then the resistance of these series are combined using the formula for resistance in parallel:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

where in this case R_T is the total resistance of the entire series-parallel circuit, and R_1 is the resistance of the first series, R_2 is the resistance of the second series, etc.

If all parallel branches are balanced, as they should be (i.e. all branches have identical resistance), the total resistance of the circuit can be found by dividing the resistance of one series by the number of series.

Problem 10: A series-parallel circuit consists of 80 caps connected into four series of 20 caps each. If these caps each have a resistance of 3.8 ohms, what is the total resistance of the entire circuit?

Solution: Step 1-Calculate the resistance of the individual series.

$$R_{series} = R_1 + R_2 + \ldots\ldots + R_{20}$$
$$R_{series} = 3.8 + 3.8 + \ldots\ldots + 3.8$$
$$R_{series} = 20 \times 3.8$$
$$R_{series} = 76 \text{ ohms}$$

Step 2 - Calculate the resistance of the branches connected in parallel.

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

$$\frac{1}{R_{total}} = \frac{1}{76} + \frac{1}{76} + \frac{1}{76} + \frac{1}{76}$$

$$\frac{1}{R_{total}} = \frac{4}{76}$$

Inverting, $R_{total} = \frac{76}{4} = 19$ ohms

Notice that in the previous example all the branches were balanced; they all had identical resistances. Therefore, the total resistance of the circuit (19 ohms) is equal to the resistance of one series (76 ohms) divided by the number of series used (4).

Problem 11: Two hundred caps having 50 foot copper legwires are connected in series parallel. The circuit is made up of 8 series, each with 25 caps. What is the total resistance of this circuit?

Solution: From Table A, a 50 ft copper legwire cap has a resistance of 2.6 ohms.

Step 1 - $R_{series} = R_1 + R_2 + \ldots\ldots R_{25}$

$R_{series} = 25 \text{ caps} \times 2.6 \text{ ohms}$

$R_{series} = 65 \text{ ohms}$

Step 2 - Since the series are balanced, the total resistance is the following:

$$R_{total} = \frac{65}{8} = 8.125 \text{ ohms}$$

Problem 12: Sixty electric blasting caps are connected in a series-parallel circuit consisting of 3 series of 20 caps each. If each cap has resistance of 2.3 ohms, what is the total resistance of this circuit?

Solution:

Problem 13: A series parallel circuit has 132 caps divided into three series of 44 caps each. The caps all have 24 foot copper legwires. What is the total resistance of this series parallel circuit?

Solution:

Problem 14: One hundred caps are wired into series parallel circuit having 5 series of 20 caps each. If the resistance of each cap is 1.5 ohms, what is the total resistance?

Solution:

Calculating Resistance of Wiring

The preceding calculations in problems 1 - 14 take into consideration only the resistance of the caps and their legwires. In an actual blasting circuit, the lead line, and any connecting wire used will also contribute some resistance to the circuit. While in most cases these items will add only a few ohms to the overall resistance, they may be critical in some blast circuits.

In pure parallel circuits and series-parallel circuits with a large number of series, the resistance of the wires may become very significant. Therefore, the resistance of the lead line and any connecting wire used should be calculated, and this value added to the resistance of the cap circuit.

When calculating the resistance of any wire, we find that it depends on the following things:

(1) Length - the longer a wire, the higher the resistance

(2) Thickness or Gauge - the thicker the conductor, the less resistance

(3) Type of metal - copper has less resistance than iron

Wire thickness or "cross-sectional area" is designated by a gauge number which can range from 0 to 24. These numbers are arranged so that the smaller the gauge number, the thicker the wires. As an example, number 10 guage wire has a larger cross-sectional area (thicker) than number 12 gauge wire.

A lead line should be gauge 12 or 14, with the 12 being preferred as it is heavier and therefore has less resistance. Connecting wire is thinner such as 18 or 20 gauge.

Table B gives the resistance per 1,000 feet of various gauges of wire.

TABLE B

Resistance of Copper and Iron Wire
Ohms/1000 ft

Gauge	Copper	Iron
6	0.39	1.4
8	0.63	3.7
10	1.00	6.1
12	1.60	9.8
14	2.53	15.6
16	4.02	24.8
18	6.38	39.5
20	10.15	62.7
21	12.80	76.1
22	16.14	100
23	20.36	126
24	25.67	159

Remember that a lead line or firing line is normally a duplex cable; that is, it is made up of two wires inside an insulating covering. This means that a lead line 250 feet long actually has two 250 foot conductors inside it, and the total length of the wire carrying current is 500 feet.

The formula for calculating resistance for any type of wire is simply the length of wire divided by 1000 times the resistance per 1000 feet.

Problem 15: What is the resistance of 600 ft of 20 gauge copper connecting wire?

Solution:

$$\text{Resistance of Wire} = \frac{\text{Length (ft)}}{1000 \text{ ft}} \times \text{Resistance from Table}$$

$$\text{Resistance of Wire} = \frac{600 \text{ ft}}{1000 \text{ ft}} \times 10.15 \text{ ohms} = 6.09 \text{ ohms}$$

Problem 16: What is the resistance of 750 ft duplex lead line of 12 gauge copper wire?

Solution:

Actual length of duplex conductor = 2 X 750 = 1500

$$R = \frac{1500 \text{ ft.}}{1000 \text{ ft}} \times 1.60 \text{ ohms} = 2.4 \text{ ohms}$$

In practical cases, the resistance of the firing line, and the resistance of any connecting wire used, is added to the resistance of the cap circuit. This total resistance is what is measured at the end of the lead line before the blasting machine is attached. It is this resistance that will determine whether or not sufficient current will be able to flow through the blasting circuit. Most generator type or CD type machines will have technical data readily available listing how much electric current or energy they will supply through a certain resistance. Each machine will be different, and you should be aware of this information in order to prevent misfires from inadequate current distribution to the caps.

Problem 17: A blasting circuit has 20 caps with 16 foot legwires connected in a single series. The wiring procedure uses 100 foot of 20 gauge copper connecting wire. The lead line is 300 feet long and made of 14 gauge copper duplex wire. Calculate the total resistance of the circuit.

Solution:

Step 1 - Calculate the resistance of caps in series.

$$R_{caps} = 20 \text{ caps} \times 1.9 \text{ ohm/cap} = 38 \text{ ohms}$$

Step 2 - Calculate the resistance of the connecting wire

$$R_{con.\ wire} = \frac{100 \text{ ft.}}{1000 \text{ ft}} \times 10.15 \text{ ohms} = 1.015 \text{ ohms}$$

Step 3 - Calculate the resistance of lead line
(Note that actual length = 2 X 300 ft)

$$R_{LL} = \frac{600 \text{ ft.}}{1000 \text{ ft}} \times 2.53 \text{ ohms} = 1.518 \text{ ohms}$$

Step 4 - The total circuit resistance is the sum of R_{caps} + $R_{con.\ wire}$ + R_{LL}.

$$R_{total} = 38 \text{ ohms} + 1.015 \text{ ohms} + 1.518 \text{ ohms} = 40.533$$

As you can see from this example, the resistance of a series circuit is predominantly due to the resistance of the caps; in this example 38 ohms out of 40.5 ohms are due to the cap resistance, only 2.5 ohms are a result of the wiring.

Problem 18: What is the resistance of the 10 gauge copper duplex firing line that is 1500 feet long?

Solution:

Problem 19: What is the resistance of 500 ft of 18 gauge copper connecting wire?

Solution:

Problem 20: Six electric blasting caps with 20 ft. copper legwires are connected in a series circuit. The blast is wired with 200 feet of 20 gauge copper connecting wire and a duplex lead line 400 feet long made of 12 gauge copper. What is the total resistance?

Solution:

Calculating Current in Blasting Circuit Using Ohm's Law

Once you have calculated the resistance of a blasting circuit,it is possible to determine the amount of current that this circuit will draw from the power source. When blasting from power lines this can be done by using Ohm's Law which says that current is equal to voltage divided by resistance. If you look at Table C on the next page for the current needed to fire electric blasting caps, you may see the usefulness of these calculations. Once the resistance of a circuit is known, it is possible to calculate how much current will flow in the circuit and predict whether this current is adequate before we attempt to fire the circuit.

TABLE C
Minimum Firing Current Standards for Typical Electric Blasting Caps

	Minimum Recommended Firing Current	
Circuit	DC Power Source	AC Power Source
single cap	0.5 amp	0.5 amp
single series	1.5 amps	2.0 amps
series parallel	1.5 amps/series	2.0 amps/series
parallel	1.0 amp/cap(min.) 10.0 amp/cap(max.)	1.0 amp/cap(min.) 10.0 amp/cap(max.)

A maximum firing current is specified for parallel circuits to prevent a condition called arcing. This maximum applies when the power source is a power line. Like the other tables in this booklet, this table of values for minimum firing current is used for example only. Various manufacturers may specify different lower minimum or maximum current for their own electric blasting caps.

Ohm's Law expressed as a formula is:

$$\text{Current (I)} = \frac{\text{Voltage (E)}}{\text{Resistance (R)}}$$

or, rearranged to find voltage:

Voltage (E) = Current (I) X Resistance (R)

Problem 21: A blasting circuit has a total resistance of 90 ohms; if it is to be shot from a 120 volt power line, what will be the current flowing in the circuit?

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

$I = \frac{120 \text{ volts}}{90 \text{ ohms}} = 1.33 \text{ amps}$

Problem 22: A current of 2.0 amps is flowing in a blasting circuit having a resistance of 80 ohms. What is the voltage of the power source supplying this?

Solution: E = I X R

E = 2.0 amps X 80 ohms

E = 160 volts

Problem 23: A power source has a voltage of 400 volts. If this is applied to a blasting circuit with a resistance of 60 ohms, what current will flow in the circuit?

Solution:

Problem 24: A blasting circuit has 6.5 amps flowing through it. If the circuit has a total resistance of 50 ohms, what is the voltage of the power source?

Solution:

Problem 25: A circuit has a total of 15 ohms resistance. If it is fired from a 120 volt power line, what is the current that will flow in the circuit?

Solution:

As mentioned previously, for blasting operations Ohm's Law is applicable only when shooting with power lines. The voltage supplied to a circuit from a condenser discharge blasting machine is not a constant value and therefore cannot be used in the Ohm's law formula. The voltage from a condenser discharge circuit usually starts at a very high value and quickly drops to zero with the majority of the energy being delivered to the cap circuit in a very short time. (approximately 5 milliseconds)

In order to determine the current that will flow from a blasting machine into any blasting circuit it is necessary to refer to a chart similar to Table D. This chart gives the equivalent current from various types of blasting machines when connected a known amount of resistance. Table D is a representative chart used only as an example, check with the manufacturer of your blasting machine for similar information.

TABLE D

CURRENT OUTPUT OF THREE TYPICAL BLASTING MACHINES

Total Circuit Resistance	REO 450	REO 600	ATLAS 800c
5 ohms	33 amps	46 amps	47 amps
10 "	25 "	34 "	29 "
15 "	20 "	27 "	21 "
20 "	16 "	22 "	16 "
25 "	14 "	18 "	13 "
30 "	12 "	16 "	11 "
35 "	10 "	14 "	9.7 "
40 "	9.5 "	12 "	8.6 "
45 "	8.6 "	11 "	7.6 "
50 "	7.9 "	10 "	6.9 "
60 "	6.7 "	9 "	5.8 "
75 "	5.4 "	7.3 "	4.7 "
100 "	4.2 "	5.6 "	3.5 "
110 "	3.8 "	5.1 "	3.2 "
150 "	2.8 "	3.8 "	2.9 "

Problem 26: A blasting circuit is a single series of 20 caps and has a total resistance of 35 ohms. How much current does each cap receive if this circuit is fired with a REO 600 blasting machine.

Solution: From Table D, a REO 600 blasting machine will supply 14 amps of current to a circuit containing 35 ohms resistance. Since this is a single series circuit, all the caps in the circuit receive the same 14 amps of current.

Problem 27: A blasting circuit consists of 45 caps connected in series, and each cap has 28 ft leg wires. The shot uses a 650 ft of 12 gauge copper duplex lead line and will be fired with a REO 450 blasting machine. How much current does each cap receive?

Solution: From Table A, the resistance of a cap with 28 ft leg wires is 2.4 ohms.

$$R_{caps} = 45 \times 2.4 \text{ ohms} = 108 \text{ ohms}$$

$$R_{lead\ line} = 2 \times 650 \times 1.6 = 2.08 \text{ ohms}$$

The total circuit resistance, $R_t = 108 + 2.08 = 110.08$ ohms

From Table D, a REO 450 blasting machine will supply 3.8 amps of current to a circuit containing 110 ohms of resistance, therefore all caps in this series will receive 3.8 amps of current.

Problem 28: A blasting circuit is a single series of 34 caps and has a total resistance of 60 ohms. How much current does each cap receive if this circuit is fired with a Atlas 800c blasting machine?

Solution:

Problem 29: A blasting circuit consists of 28 caps connected in series, and each cap has 40 ft leg wires. The shot uses a 2000 ft of 14 gauge copper duplex lead line and will be fired with a REO 600 blasting machine. How much current does each cap receive?

Solution:

As mentioned in the discussion on the characteristics of a single series, current will be the same in all parts of a series circuit. Therefore, when doing a current calculation using either Ohm's Law or the Table for blasting machines, the resulting current in a series circuit will flow through <u>all</u> caps in that series.

However, in a parallel, or series-parallel circuit, this is not true. The current flowing from the power source is divided among the various parallel branches.

If the resistance of all parallel branches are equal, the current will be distributed evenly to each branch. For example, in a blasting circuit consisting of 5 balanced parallel branches and drawing 10 amps of current from the power supply, each branch (and all caps in that branch) will get 2 amps of current. According to the table of minimum firing currents, this amount is sufficient to reliably fire the caps. However, a blasting circuit which has 5 balanced parallel branches and is provided with only 4 amps of current by the power supply, will not provide enough current to each cap to reliably fire them. (4 amps divided by 5 branches equal 0.8 amps per series; 1.5 amps per series is required for reliable detonation)

Problem 30: A circuit consists of 4 parallel branches and it has a total resistance of 60 ohms. If it is fired using an REO 600 blasting machine, how much current does each cap receive?

Solution: From Table C, a REO 600 provides 9 amps of current to a circuit with 60 ohms of resistance. Since there are four balanced branches in this circuit, the current is distributed evenly through all four branches. The current in each branch or series is therefore: 9/4 = 2.25 amps. This quantity is greater than the minimum firing current of 1.5 amps per series.

Problem 31: A circuit consists of 8 parallel branches and has a total resistance of 100 ohms. If it is fired with an Atlas 800c blasting machine, how much current flows through each of the caps? Is it enough to reliably fire the caps?

Solution:

Construction of Electric Blasting Cap

The diagram on the following page illustrates the construction of typical instantaneous and delay electric blasting caps. When electric current passes through the bridge wire, it causes it to heat up in a manner similar to the filament of a light bulb. since the bridge wire is in contact with a heat sensitive chemical called the ignition compound, the bridge wire causes the ignition compound to begin to burn. In an instantaneous cap, this burning of the ignition compound will cause detonation of a primer charge inside the cap which in turn sets off the base charge.

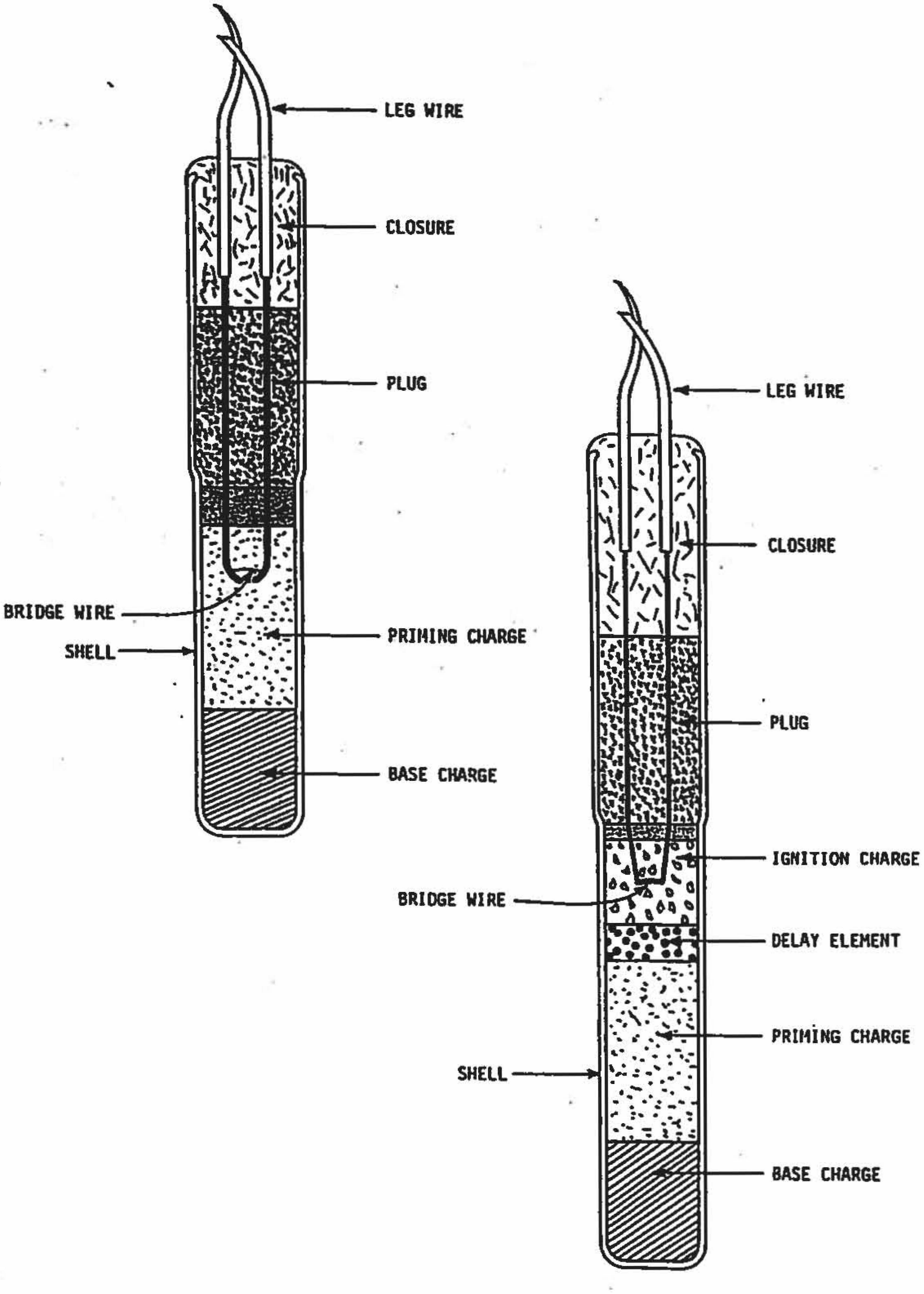
In a delay cap there is a column of powder between the ignition compound and the primer charge called the delay element. This element slows the progression of burning inside the cap for a pre-determined length of time. This length of time can vary from a few milliseconds to several seconds.

Note that this delay is not governed by the electric current applied to the cap, but by this delay element within the cap itself. All caps in a firing circuit receive the current at the same time; the time interval between application of current to the bridge wire and detonation of the base charge is determined by the burning of the delay element in the cap.

Arcing is a serious malfunction that can occur when electric blasting caps receive too much electrical energy. Too much electrical energy means that the ampsof current is too high and it is applied for too long a time. This generates an excessive amount of heat in the cap and may result in the cap rupturing and causing a misfire or a hangfire. A hangfire means the explosives in the borehole catch fire and may detonate at any time. It is a very dangerous situation since it may be several seconds or several minutes until detonation occurs and the blaster is usually unaware of this potential hazard.

DIAGRAM OF ELECTRIC BLASTING CAPS

Instantaneous and Delay Types



The Classification and Properties of Explosives

The chart on the following page shows the classification of explosives by types and contains a brief description of each based upon their composition and properties.

A high explosive is distinguished from a low explosive by the fact that a low explosive does not generate a shock wave when initiated. The reaction in a low explosive, such as black powder, is properly called a deflagration which is a rapid burning producing large quantities of gases. A detonation which occurs when high explosives are initiated will also produce a large amount of high temperature and high pressure gases, but the shock wave that is created and sustained distinguishes this reaction from a deflagration.

The difference between a high explosive and a blasting agent is their sensitivity to a blasting cap. A blasting agent will not detonate with a blasting cap alone, it requires a primer cartridge of high explosive to initiate it. However, a high explosive will detonate when a blasting cap if fired in contact with it.

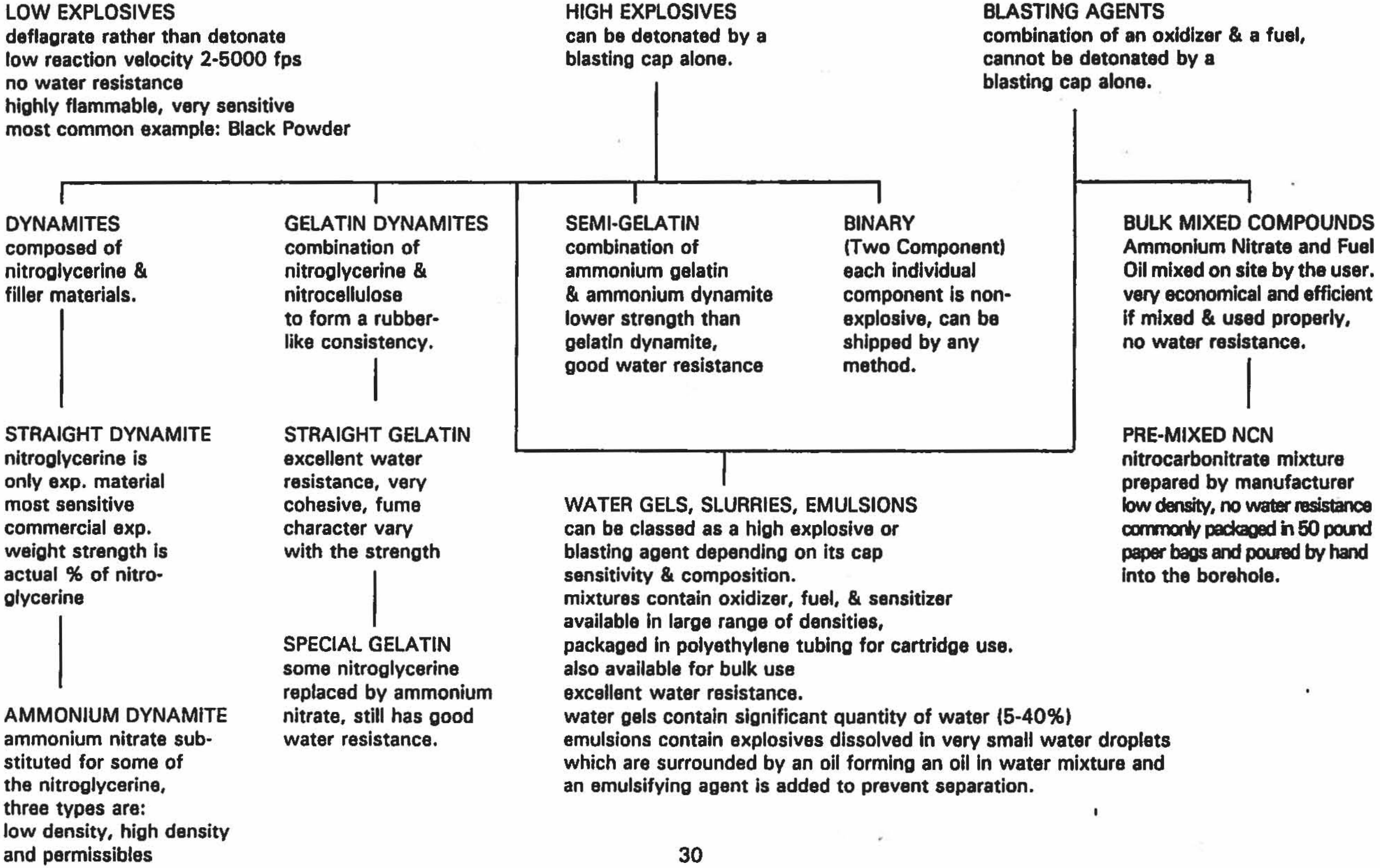
In selecting an explosive to be used, the blaster must know the conditions he will be working under and he must thoroughly understand which properties of the explosive are desirable for these circumstances.

The properties or characteristics of explosives are:

1. Density
2. Water Resistance
3. Detonation Velocity
4. Strength
5. Fume Characteristic
6. Sensitivity
7. Sensitiveness.

Each of these terms are in the section of definitions in the beginning of this booklet.

CLASSIFICATION OF EXPLOSIVES



LOW EXPLOSIVES
deflagrate rather than detonate
low reaction velocity 2-5000 fps
no water resistance
highly flammable, very sensitive
most common example: Black Powder

HIGH EXPLOSIVES
can be detonated by a
blasting cap alone.

BLASTING AGENTS
combination of an oxidizer & a fuel,
cannot be detonated by a
blasting cap alone.

DYNAMITES
composed of
nitroglycerine &
filler materials.

STRAIGHT DYNAMITE
nitroglycerine is
only exp. material
most sensitive
commercial exp.
weight strength is
actual % of nitroglycerine

AMMONIUM DYNAMITE
ammonium nitrate substituted for some of
the nitroglycerine,
three types are:
low density, high density
and permissibles

GELATIN DYNAMITES
combination of
nitroglycerine &
nitrocellulose
to form a rubber-like consistency.

STRAIGHT GELATIN
excellent water
resistance, very
cohesive, fume
character vary
with the strength

SPECIAL GELATIN
some nitroglycerine
replaced by ammonium
nitrate, still has good
water resistance.

SEMI-GELATIN
combination of
ammonium gelatin
& ammonium dynamite
lower strength than
gelatin dynamite,
good water resistance

BINARY
(Two Component)
each individual
component is non-explosive, can be
shipped by any
method.

WATER GELS, SLURRIES, EMULSIONS
can be classed as a high explosive or
blasting agent depending on its cap
sensitivity & composition.
mixtures contain oxidizer, fuel, & sensitizer
available in large range of densities,
packaged in polyethylene tubing for cartridge use.
also available for bulk use
excellent water resistance.
water gels contain significant quantity of water (5-40%)
emulsions contain explosives dissolved in very small water droplets
which are surrounded by an oil forming an oil in water mixture and
an emulsifying agent is added to prevent separation.

BULK MIXED COMPOUNDS
Ammonium Nitrate and Fuel
Oil mixed on site by the user.
very economical and efficient
if mixed & used properly,
no water resistance.

PRE-MIXED NCN
nitrocarbonitrate mixture
prepared by manufacturer
low density, no water resistance
commonly packaged in 50 pound
paper bags and poured by hand
into the borehole.

When loading a borehole, the density of the explosive will determine how many pounds of explosives can be loaded into a certain size borehole. A high density explosive is concentrated and will enable the blaster to load more explosives per foot of borehole than a low density explosive would. ANFO, the most common explosive used, has a relatively low density. However, it is possible to mix ANFO and emulsions by use of a special blending truck which allow the blaster to vary the density of his blasting agent mixture within the same borehole.

When loading any explosive in a borehole containing water, it is important that the explosive's density be greater than the density of water. If not, the explosive will float and the charge column will become separated causing misfires. The specific gravity of water is 1.00, therefore any explosive used is a borehole with water must have a specific gravity greater than 1.00.

The water resistance of an explosive is also important in such a case, since it is a measure of how much exposure to water the explosive can withstand without becoming desensitized or inefficient. This property is described in qualitative terms such as good, fair, poor, etc. Water gels, slurries, gelatins, and high density explosives have good to excellent water resistance. The low density, porous explosives, such as ammonia dynamites have poor water resistance. When loaded in bulk, ANFO has extremely poor water resistance.

The detonation velocity of an explosive is considered by many blasters to be important in breaking hard, massive rock formations. High velocity explosives expend a greater percentage of their energy in the creation of shock wave when detonated. This shock wave has more of a shattering effect on the rock. Explosives with a lower velocity concentrate more of their energy in the formation of gas pressure which has a heaving or lifting action. This has the best results in rock which is softer and has thin seams or layers.

The strength of an explosive can be expressed and measured in a number of ways. Weight strength can be indicated by a percentage. Many years ago, 60% straight dynamite actually meant that the dynamite was composed of 60 % nitroglycerine and 40% other materials. However as the chemistry of explosives became more advanced, many other ingredients were commonly substituted for nitroglycerine. Today the listed percentage does not reflect the actual amount of nitroglycerine but is used for comparison only. For instance, a modern explosives such as 40% gelatin does not contain 40% nitroglycerine, but can be considered to have a strength equal to a straight dynamite that would contain 40% nitroglycerine.

Many manufacturers are now precisely measuring the energy of their explosives in terms of calories per gram, foot-lb per pound, or other scientific units. For a blaster in the field, the higher strength explosive should enable him to get better fragmentation with no change in pattern, or enable him to expand his blasting pattern with no loss of efficiency. It is the explosive strength (or energy) that is doing the work of breaking and moving the rock.

A blast produces large quantities of gases, carbon dioxide, carbon monoxide, and steam, as well as toxic oxides of nitrogen. The fume characteristics of an explosive is a measure of the quantity of poisonous fumes produced by detonation. These fumes can be very hazardous even in small concentrations. When blasting on the surface the fumes are usually dispersed rapidly by the air. However in a confined area, such as a tunnel, it is important to use an explosive which produces a minimum amount of toxic gases, in addition to providing adequate ventilation. The Institute of Makers of Explosives and the U. S. Bureau of Mines both have methods of classifying explosives according to the amount of toxic fumes they produce when detonated.

The manner in which explosives are detonated can also effect the quantity of fume production. For example, ANFO when mixed in proper proportions and well confined, and detonated in a dry borehole will produce a minimum amount of fumes. However, if detonated when poorly confined, wet, or with an unbalanced mixture of Ammonium Nitrate and Fuel Oil, it can produce large quantities of orange-brown oxides of nitrogen.

The sensitivity of a high explosive must be such that it will reliably detonate with a blasting cap, yet it cannot be so sensitive to shock, heat, or friction that it is unsafe to handle. The sensitivity of blasting agent will depend upon its composition and this will determine what type of primer must be used to initiate it.

Sensitiveness is the ability of an explosive to propagate continually once it has been initiated, that is, the detonation will not die out in the charge column. Explosives with extreme sensitiveness may detonate when the shock wave from an adjacent hole reaches them. This hole to hole propagation will most likely occur when very sensitive high explosives are used in boreholes drilled very close together. Such propagation is a serious problem because it disturbs or destroys the delay pattern planned for the shot and can result in excessive flyrock or very high vibration levels.

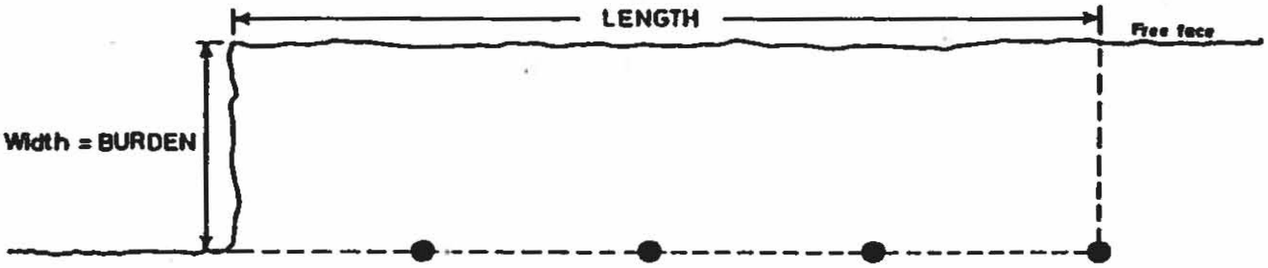
When evaluating all these properties of explosives, the blaster must rely on the explosive manufacturers for information and advice in order to make the right choices. He must be aware of changing conditions and thoroughly understand the properties which are only briefly summarized here.

Blasting Mathematics

For both the blaster's examination, and when working in the field, there are some basic calculations a blaster needs to know how to do.

Determining the Volume of Rock Broken

When first planning a shot, consideration must be given to how much rock will be broken by the shot, and how much will be broken by each borehole. The volume of rock to be fragmented will be defined by the geometry of the blast pattern. The shot may be very simple, such as a single row breaking to an open face as shown below.

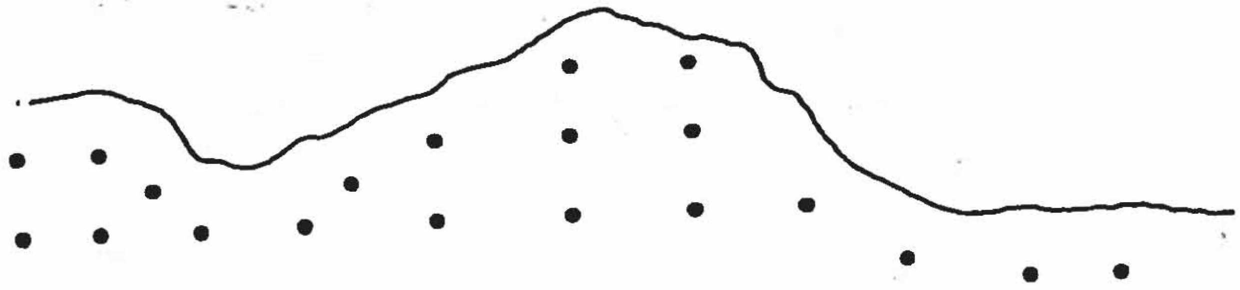


The solid line would indicate the existing face of rock before the shot is detonated. The dashed line indicates where the rock face will be after detonation. The area between the two lines represents the fragmented rock. To calculate the volume of the broken rock, multiply the area times the height of the rock or use the formula for volume of a rectangular solid which is:

Volume = Length X Width X Height

In this case the length is the length of the shot, the width is equal to the burden, and the height is the depth of the rock. *Any subdrilling is not considered as part of the height in calculating volume.* The height is the depth of the borehole minus any subdrilling and this should correspond to bench height. In trench line excavation, the height is the actual distance from the top of rock to grade. This type of trench involves drilling through the "overburden" which is the dirt and loose material overlaying the rock. When boreholes are drilled through this overburden to the rock, *the depth of the overburden is not included in the height of the rock.*

In a more complicated or irregular shot pattern such as below, it is not as easy to calculate the total volume of the rock broken.



In this case, the standard method for finding rock broken by a blast is to calculate the volume broken by a single borehole and multiply by the number of holes. This can be used in both simple and complex patterns and will give good approximations of the rock produced by a blast.

If burden, spacing, and depth are measured in feet, the volume of rock in cubic yards is given by the following formula:

$$\underset{(Yd^3)}{\text{Volume}} = \frac{\text{Burden (ft) X Spacing (ft) X Depth (ft)}}{27}$$

The 27 is a conversion factor to change cubic feet to cubic yards, (1 yd^3 = 27 $ft.^3$.)

Problem 32: A borehole is drilled on a 10' X 12' pattern 30 feet deep. How many cubic yards of material will this hole break?

Solution:

$$\text{Volume} = \frac{\text{Burden X Spacing X Depth}}{27}$$

$$\text{Volume} = \frac{10 \text{ X } 12 \text{ X } 30}{27} = \frac{3600}{27}$$

$$\text{Volume} = 133.3 \text{ yd}^3$$

Problem 33: A borehole is drilled on a 3' X 4' pattern 12 feet deep. The bench height is 10 feet and the borehole have been subdrilled 2 feet. How many yd^3 of rock will be broken to grade?

Solution:

$$\text{Volume} = \frac{3 \text{ X } 4 \text{ X } 10}{27} = \frac{120}{27} = 4.44 \text{ yd}^3$$

Problem 34: A shot consists of 80 holes drilled on a square 10' X 10' pattern. The depth of the borehole is 30 feet; the subdrilling is 3 feet. How many yd^3 of material will be broken to grade by the entire blast?

Solution:

$$\text{Volume} = \frac{10 \text{ X } 10 \text{ X } 27}{27} = 100 \text{ yd}^3$$

Total volume of shot = # of holes X volume per borehole
Total volume of shot = 80 X 100
Total volume of shot = 8000 yd^3

Problem 35: A borehole is drilled on a 12' X 15' pattern with a depth to grade of 45 feet. How many yd^3 of material is broken by this borehole?

Solution:

Problem 36: A shot pattern has 20 holes drilled on a 2' by 3' pattern. The rock depth is 6 feet; of this, there is 1 foot of subdrilling. How many yd^3 of rock will be broken to grade by this shot?

Solution:

Problem 37: Thirty-five boreholes are drilled on a 7' X 9' pattern and 15 feet deep. No subdrilling is used. How much material is broken by this shot?

Solution:

Calculating Powder Factor

Powder factor is defined as the ratio of a quantity of explosives needed to break a quantity of rock. By this definition powder factor could be expressed as pounds of explosives per ton of rock (lb/ton), pounds of explosive per cubic yard of rock (lb/yd^3), or in any other units of measure that would specify explosives and rock amounts. Pounds per cubic yard seems to be the most widely accepted form of expressing the powder factor, and the one on which the following problems are based.

The powder factor will vary for all blasting operations depending on how hard the rock is, the density and strength of the explosive used, the blast pattern, the geology, the degree of fragmentation required as well as a host of other factors.

On large scale operations such as quarries, mines, and highway excavation, powder factors may vary from 0.5 lb/yd^3 to 2.0 lb/yd^3. For smaller operations, powder factors may range from 1.0 lb/yd^3 for wide trenches and easy shooting to 8.0 lb/yd^3 for narrow trenches and hard shooting.

The normal way of calculating powder factor is to find the cubic yards of rock a borehole will break and divide this into the pounds of explosive loaded in that borehole:

$$\text{Powder Factor (lb/yd}^3\text{)} = \frac{\text{amount of explosive (lb)}}{\text{volume of rock broken (yd}^3\text{)}}$$

Powder factor can also be used as a method of blast design or at least as a way of determining the amount of explosives to be used in a borehole. The formula above can be rewritten as :

$$\text{Pounds of Explosives} = \text{Powder Factor} \times \text{Volume of Rock Broken}$$

This assumes that the blaster has experience with the type of blasting to be done and knows the powder factor to be used and can calculate the volume of the rock from the burden, spacing, and depth of rock.

Problem 38: A boulder 5 yd^3 in volume is broken with a mudcap charge of 15 pounds of explosives. What is the powder factor for this shot?

Solution: $$\text{P.F.} = \frac{\text{pounds of explosive}}{\text{cubic yards of rock}}$$

$$\text{P.F.} = \frac{15\ \text{lb}}{5\ \text{yd}^3} = 3\ \text{lb/yd}^3$$

Problem 39: A borehole will break 100 yd^3 of material. If 130 pounds of explosives are loaded into the hole, what is the powder factor?

Solution: $$\text{P.F.} = \frac{130\ \text{lb}}{100\ \text{yd}^3} = 1.3\ \text{lb/yd}^3$$

Problem 40: A blast is drilled on a 12' X 15' pattern, 40 feet deep. Each hole contains 300 pounds of explosive. What is the powder factor?

Solution: $$\text{Volume of rock broken} = \frac{\text{burden x spacing x depth}}{27}$$

$$\text{Volume of rock broken} = \frac{12 \times 15 \times 40}{27} = \frac{7200}{27}$$

$$\text{Volume of rock broken} = 266.67\ \text{yd}^3$$

$$\text{Powder Factor} = \frac{\text{pounds of explosive}}{\text{cubic yards of rock}}$$

$$\text{Powder Factor} = \frac{300\ \text{lb}}{266.67\ \text{yd}^3}$$

$$\text{Powder Factor} = 1.125\ \text{lb/yd}^3$$

Problem 41: A blaster has drilled a pattern of 18 ft by 21 ft and 60 feet deep. He wants to use a powder factor of 1.20 lb/yd^3, how much explosives must he put in each borehole?

Solution: $$\text{Volume of rock to be broken} = \frac{\text{burden x spacing x depth}}{27}$$

$$\text{Volume of rock to be broken} = \frac{18 \times 21 \times 60}{27}$$

$$\text{Volume of rock to be broken} = 840\ \text{yd}^3$$

$$\text{Pounds of explosives} = \text{powder factor x yd}^3 \text{ of Rock to be broken}$$

$$\text{Pounds of explosives} = 1.2 \times 840 = 1008\ \text{lb/hole}$$

For this blast design to work, the borehole drilled must be large enough to hold 1008 pounds of explosives and still have room for an adequate amount of stemming. Obviously if a blaster designs a pattern with a large burden and spacing such as above, he must have a large diameter drill.

Problem 42: A borehole contains 550 pounds of explosive. The rock to be broken by this borehole is 450 cubic yards. What is the powder factor?

Solution:

Problem 43: A blast is drilled on a 7′ x 7′ pattern, 30 feet deep. Each hole contains 75 pounds of explosive. What is the powder factor?

Solution:

Problem 44: A borehole is drilled with a 9 foot burden, 12 foot spacing, and 24 feet deep. Of this 24 foot depth, 3 feet is subdrilling. The borehole contains 60 pounds of explosive. What is the Powder Factor?

Solution:

Problem 45: A blast is drilled with an 11.5′ X 13.5′ spacing 50 feet deep (no subdrilling). The boreholes each contain 300 pounds of explosive. What is the powder factor?

Solution:

Problem 46: A blaster is using a powder factor of 0.75 to blast some shale for a highway project. If his pattern is drilled on a 12 ft by 15 ft pattern, 24 feet deep, how many pounds of explosive must he load in each borehole?

Solution:

Problem 47: A blaster is shooting a trench and must use a powder factor of 5.4 lb/yd^3 in order to break the rock to grade line. He is using an air track drill with 4 inch diameter drill bit, and his burden and spacing is 4 ft. by 6 ft. He is drilling through 8 ft of loose overburden and then 5 feet of rock. How many pounds of explosives must he load in this borehole to break the 5 ft of rock?

Solution:

Problem 48: A blaster drills a shot with 40 boreholes on a pattern of 16 ft. by 24 ft. and 80 ft deep. His powder factor is 1.0 lb/yd^3. How many pounds of explosives is required to load all 40 boreholes?

Solution:

Loading Factor

The loading factor for a particular borehole is the weight of explosives loaded per foot of borehole. The numerical value of a loading factor is determined by the diameter of the explosive column and the specific gravity of the explosive.

When using a free flowing or bulk explosive such as ANFO, the diameter of the explosive column will match the borehole diameter. A rigid cartridge will have a diameter smaller than the borehole diameter unless the cartridge is slit and tamped so that it completely fills the borehole.

Loading factors are usually available in a chart listing hole diameter and specific gravity as the two variables, and giving the pounds per foot of borehole for every combination of the variables. The table on the following page is a typical one. To use it, for example, the loading factor for a 5-inch diameter explosive column using an explosive with a specific gravity of .8, you read down the left hand column to 5 and under the top row at 0.80. The intersection of this row and column gives the loading factor of 6.81 pounds per foot.

To find the total amount of explosives in the borehole, the loading factor is multiplied by the height of the explosive column. This height corresponds to the borehole depth minus the stemming length. *Any subdrilling is included in the explosive column since subdrilling is loaded.*

Problem 49: A borehole is 30 feet deep, and 6 inches in diameter. Stemming is held to 7 feet. Using ANFO with a specific gravity of 0.8, how many pounds of explosive are loaded into this hole?

Solution: From the table, the loading factor is 9.81 lb/ft

The height of the explosive column = 30 feet - 7 feet = 23 feet

Pounds of explosive = height of explosive column X loading factor

Pounds of explosive = 23 feet X 9.81 lb/ft
Pounds of explosive = 225.6 lb

Pounds of Explosives per Foot of Borehole for Given Specific Gravity

Explosive Column Diameter in Inches	Specific Gravity										
	0.80	0.85	0.90	0.95	1.00	1.05	1.10	1.20	1.25	1.30	1.40
1	0.27	0.29	0.31	0.32	0.34	0.36	0.37	0.41	0.43	0.44	0.48
1⅛	0.34	0.36	0.38	0.41	0.43	0.45	0.47	0.52	0.54	0.56	0.60
1¼	0.42	0.45	0.48	0.50	0.53	0.56	0.58	0.64	0.67	0.69	0.74
1½	0.61	0.65	0.69	0.73	0.77	0.80	0.84	0.92	0.96	0.99	1.07
1¾	0.83	0.89	0.94	0.99	1.05	1.10	1.15	1.25	1.31	1.36	1.46
2	1.09	1.16	1.23	1.30	1.36	1.43	1.50	1.64	1.70	1.77	1.91
2¼	1.38	1.47	1.55	1.64	1.73	1.81	1.90	2.07	2.16	2.77	2.98
2½	1.70	1.81	1.91	2.02	2.13	2.23	2.34	2.55	2.66	2.77	2.98
2¾	2.06	2.19	2.32	2.44	2.57	2.70	2.83	3.09	3.22	3.34	3.60
3	2.45	2.60	2.76	2.91	3.06	3.22	3.37	3.68	3.83	3.98	4.29
3½	3.33	3.54	3.75	3.96	4.16	4.37	4.58	5.00	5.20	5.42	5.83
4	4.35	4.62	4.89	5.16	5.44	5.71	5.98	6.52	6.80	7.07	7.61
4½	5.51	5.85	6.19	6.54	6.88	7.23	7.57	8.26	8.60	8.95	9.63
5	6.81	7.22	7.65	8.07	8.50	8.93	9.35	10.20	10.62	11.05	11.90
5½	8.23	8.74	9.25	9.77	10.28	10.80	11.31	12.34	12.85	13.37	14.39
6	9.81	10.40	11.01	11.62	12.24	12.85	13.46	14.68	15.30	15.91	17.13
6¼	10.63	11.29	11.95	12.62	13.28	13.95	14.61	15.94	16.60	17.27	18.59
6½	11.49	12.21	12.93	13.65	14.36	15.08	15.80	17.24	17.95	18.67	20.11
6¾	12.39	13.17	13.94	14.72	15.49	16.27	17.04	18.59	19.36	20.14	21.69
7	13.33	14.16	15.00	15.83	16.66	17.50	18.33	20.00	20.83	21.66	23.33
7½	15.30	16.26	17.21	18.17	19.13	20.08	21.04	22.95	23.91	24.87	26.78
7⅞	16.87	17.92	18.97	20.03	21.08	22.14	23.19	25.30	26.35	27.41	29.51
8	17.41	18.50	19.59	20.68	21.76	22.85	23.94	26.12	27.20	28.29	30.47
9	22.03	23,41	24.78	26.16	27.54	28.91	30.29	33.04	34.42	35.80	38.55
9⅞	26.52	28.18	29.84	31.50	33.15	34.81	36.47	39.79	41.44	43.10	46.42
10	27.20	28.90	30.60	32.30	34.00	35.70	37.40	40.80	42.50	44.20	47.60
10⅝	30.71	32.62	34.54	36.46	38.38	40.30	42.22	46.06	47.98	49.90	53.73
12¼	40.81	43.37	45.92	48.47	51.02	53.57	56.12	61.22	63.77	66.32	71.43
15	61.20	65.03	68.85	72.68	76.50	80.33	84.15	91.80	95.63	99.45	107.1

Problem 50: A 4 inch diameter hole is loaded with 3 ½ inch rigid cartridges of explosive having a specific gravity of 1.3. If the explosive column is 12 feet high, how many pounds are loaded into the hole?

Solution: **Loading factor is 5.42 lb/ft**

Pounds of explosive = 12ft X 5.42 lb/ft = 65.04 lb

Problem 51: A 4 ½ inch borehole is loaded with a bulk slurry having specific gravity of 1.10. The hole is 40 feet deep and stemming is held at 5 feet. How many pounds of explosive are loaded into this hole?

Solution:

Problem 52: A 6 ¾ inch hole is loaded with a bulk explosive having specific gravity of 1.05. If the borehole to be loaded is 60 feet deep, and stemming is 12 feet, how many pounds of explosives are in the hole?

Solution:

Problem 53: A 5 inch hole is loaded with 4 inch rigid cartridges having a specific gravity of 0.9. A borehole is 36 feet deep and stemming is 6 feet. What is the quantity of explosive in the borehole?

Solution:

Scale Factor

The amount of explosives per delay a blaster can detonate is limited by law in the Commonwealth of Kentucky. This limit is determined by the distance from the blast site to the "nearest dwelling house, public building, school, church, commercial or institutional building". The purpose of limiting the pounds per delay is to ensure that the resulting ground vibrations stay below the levels that are illegal.

For contractors, rock quarries, and other general types of blasting, the ground vibration limit is 2.0 inches/second. The formula for determining the maximum lb/delay to ensure this limit is: $W = (D/50)^2$

where W = lb/delay, D = distance from the blast to the nearest structure.

In this formula, the number 50 is called a scale factor. The higher the scale factor used, the less explosives permitted by the formula. This formula is only applicable to distances greater than 300 feet. For distances less that 300 feet, the blaster can use 1 lb of explosives for the first 30 feet and an 1/8 of a pound for each foot beyond 30 up to a maximum of 34.6 pounds at 299 feet. This type of calculation is valid for contractors, rock quarries and demolition blasting.

Blasters working on surface coal mines have several different scale factors to contend with. These correspond to the various limits on ground vibrations as shown in the following table.

Distance from Blast Site to Nearest Structure	Maximum allowable Peak Particle Velocity	Scale-distance Equations
0 -300 ft.	1.25 in/sec	$W = (D/50)^2$
301 - 5000 ft.	1.00 in/sec	$W = (D/55)^2$
5001 + beyond	0.75 in/sec	$W = (D/65)^2$

Problem 54: A road contractor is blasting within 700 feet of a school. How many lb/delay can he legally detonate?

Solution:

$$W = (D/50)^2$$

$$W = (700/50)^2 = (14)^2 = 196 \text{ lb/delay}$$

Problem 55: A surface coal operator is blasting within 880 feet of a house. How many pounds per delay can he legally detonate?

Solution:

$$W = (D/55)^2$$

$$W = (880/55)^2 = (16)^2 = 256 \text{ lb/delay}$$

Problem 56: A quarry operates within 1000 feet of the nearest house. The quarry uses small diameter holes and loads 50 lb of explosives in each borehole. How many holes can be detonated legally in any one delay period?

Solution:

$$W = (D/50)^2$$

$$W = (1000/50)^2$$

$$W = (20)^2 = 400 \text{ lb/delay}$$

Since 400 lb/delay can legally be detonated and the quarry loads 50 lb/hole, the quarry can detonate 8 holes per delay and be in compliance with the law.

Problem 57: A contractor is blasting 1250 feet away from the nearest house. How many pounds per delay can he detonate?

Solution:

Problem 58: A surface coal operator is blasting 250 feet away from the nearest house. How many pounds per delay can he detonate?

Solution:

Problem 59: A quarry is blasting 600 feet from a house. The normal blast pattern used has boreholes containing 120 pounds each. How many holes can legally be detonated on a single delay?

Solution:

Problem 60: A surface coal mine is blasting within 5,850 feet of the nearest house. If his pattern calls for each hole to be loaded with 2,000 pounds of explosives, how many of these holes can be legally detonated on a single delay?

Solution:

Problem 61: A utility contractor is blasting 86 feet away from the nearest dwelling. How many pounds per delay can he detonate?

Solution:

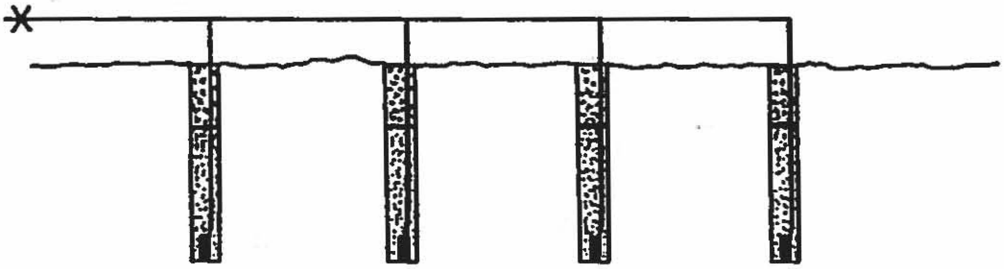
Detonating Cord Delay Patterns

When detonating cord is used to initiate a pattern of blast holes, the holes are all considered as detonating at the same time. This is due to the high detonation velocity of d-cord (21,000 - 23,000 fps). The initiation is carried from hole to hole in a very short time, for example, only ½ millisecond for 13 foot of detonating cord. There are two ways to create delays in a shot initiated with detonating cord:

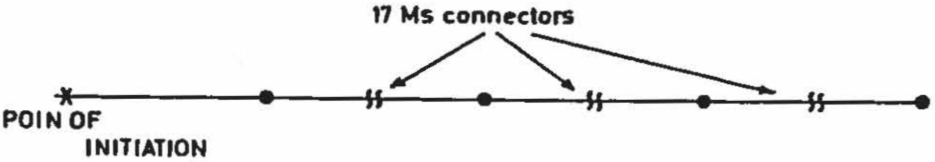
1. D-cord blasting caps, such as primadets, which are down-hole devices with the delay built in the cap in the same manner as electric delay cap.

2. Delay connectors which are spliced into a length of detonating cord and slow the detonation by a precise time, usually 9, 17, or 25 milliseconds.

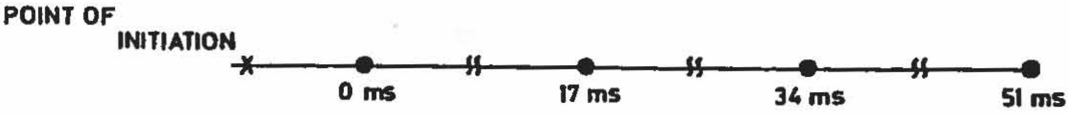
If a single row of holes is loaded with high explosives tied to downlines of detonating cord, and these downlines are connected to a trunkline of d-cord, as shown below, when the d-cord is initiated at the end the detonation of all four boreholes will occur nearly simultaneously. Therefore, all four boreholes are considered as detonating during 1 delay interval.



Next, consider the following diagram of the same shot but looking down at the top of the boreholes. Now however, a 17 millisecond connector is inserted between adjacent holes.



When the trunkline is initiated at the point shown, detonation will travel to the first borehole immediately. The first hole is said to fire instantaneously, i.e., with 0 milliseconds delay. The detonation then travels down the trunkline and is slowed for 17 ms by the connector before proceeding to the second borehole. The second hole, therefore, fires 17 ms after initiation. Detonation continues down the line and is delayed another 17 ms before it reaches the third boreholes. This hole will fire 34 ms after the d-cord is initiated. Likewise, the fourth hole will fire 17 ms later, at 51 ms after initiation. The effect of splicing the connectors in the trunkline is that each hole fires at a different time, and each hole, therefore, is in a separate delay interval. The following would show the firing times of each hole with 0 millisecond denoting the exact time the cord is initiated.

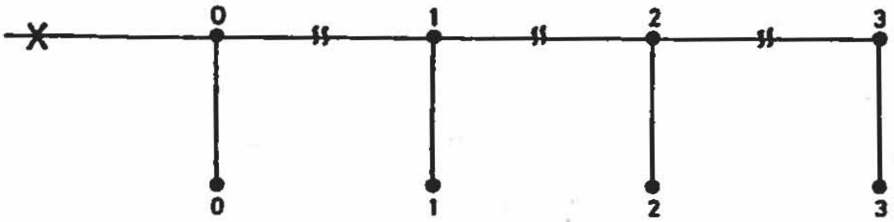


By replacing the 17 ms connectors with 25 ms connectors, the times will change as shown. However, the delay intervals, 0, 1, 2, 3, indicate that the detonation carries on as before.

The zero indicates no delay, the 1 indicates the first delay interval, the 2 indicates the second delay interval, etc.

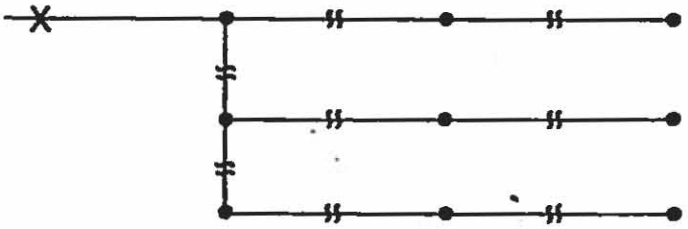
Problem 62: Given the following pattern with ms connectors inserted as shown by parallel curved lines ( ), how many holes are firing in a single delay interval?

Solution: Using numbers to indicate delay intervals

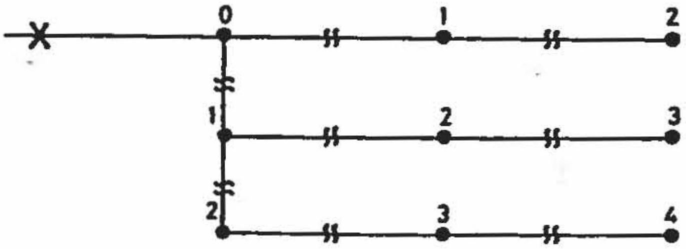


There are two holes firing per delay interval.

Problem 63. Given the following pattern using ms connectors, what is the maximum number of holes detonated in any delay interval?

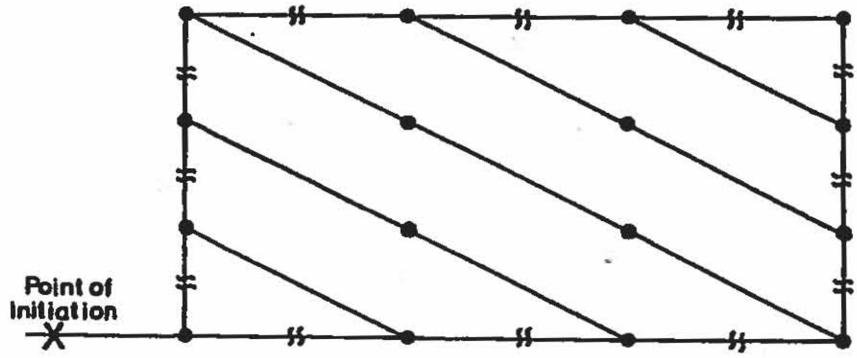


Solution: The delay intervals are:

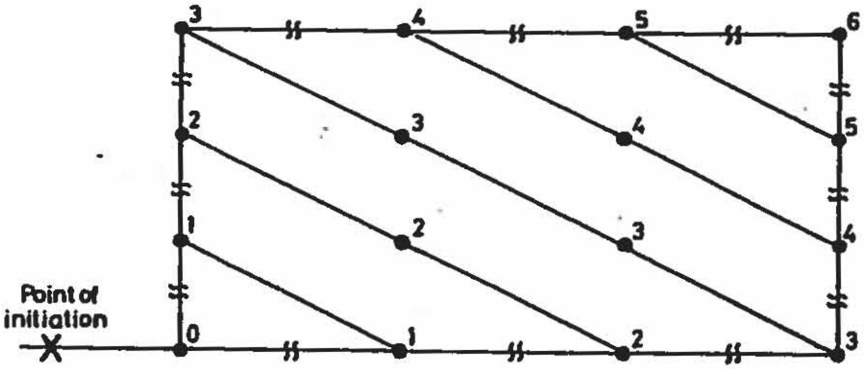


There is a maximum of 3 holes firing in the second delay interval.

Problem 64: In the following pattern, each hole contains 75 pounds of explosive. If these holes are shot using ms delay connectors as shown, what will be the maximum pounds detonated during any delay interval?



Solution: The delay intervals are as shown:

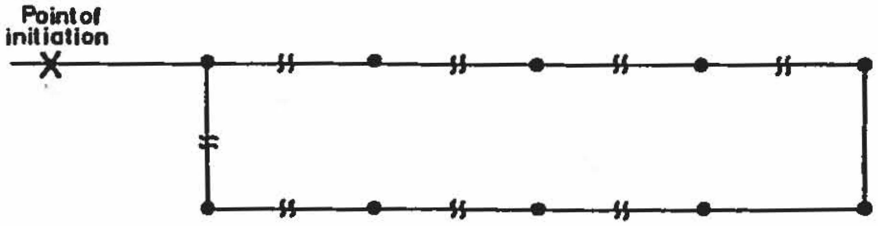


The pounds per delay is found by multiplying the number of holes per interval by the pounds per hole.

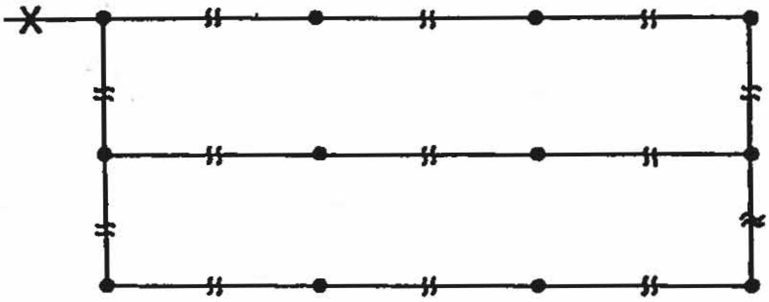
During	#0 delay interval,	1 hole fires	and 75 lb. detonates
"	#1 " "	2 " "	and 150 " "
"	#2 " "	3 " "	and 225 " "
"	#3 " "	4 " "	and 300 " "
"	#4 " "	3 " "	and 225 " "
"	#5 " "	2 " "	and 150 " "
"	#6 " "	1 " "	and 75 " "

Therefore, the maximum pounds per delay is 300, fired in the #3 interval.

Problem 65: In the following pattern of borehole connected with d-cord and ms connectors, what is the maximum number of holes fired during any delay interval?

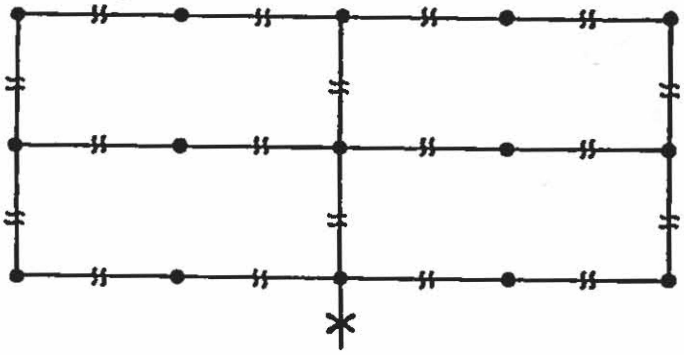


Problem 66: In the following pattern each hole contains 100 pounds of explosives. They are fired using detonating cord and ms connectors as illustrated. What is the pounds per delay for <u>each</u> interval?



Solution:

Problem 67: The following pattern has 75 pounds of explosives per hole. The pattern is laid out as shown with d-cord and ms connectors; what is the maximum lb/delay detonated?



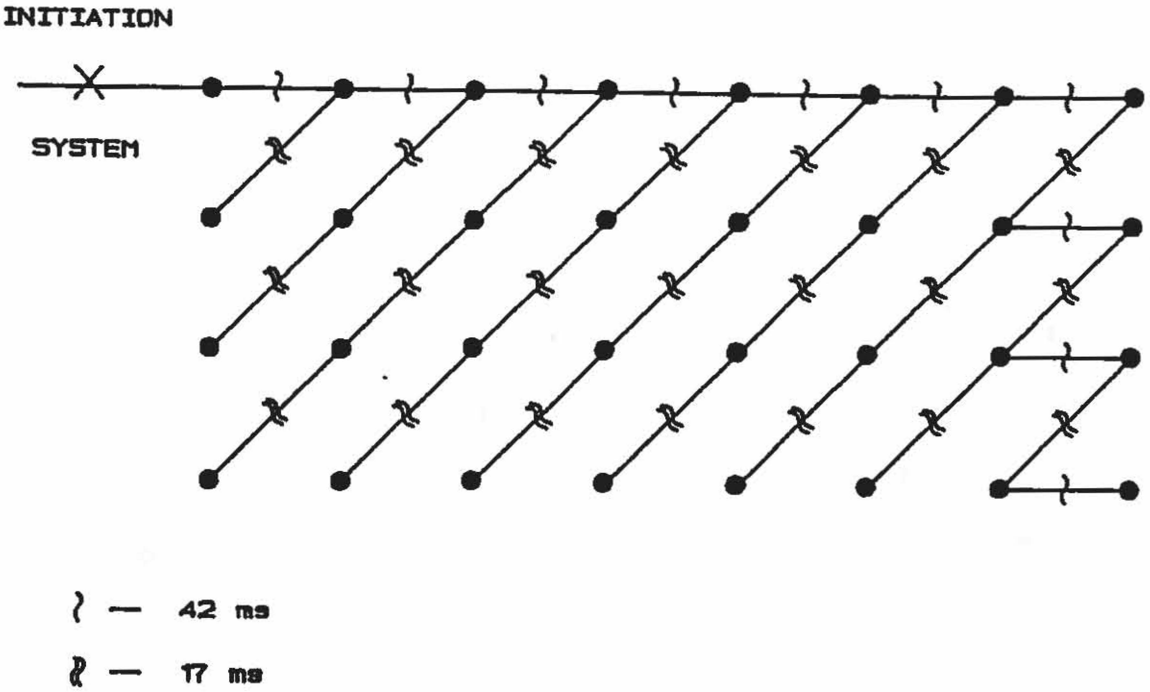
Solution:

Other Non-electric Initiation Systems

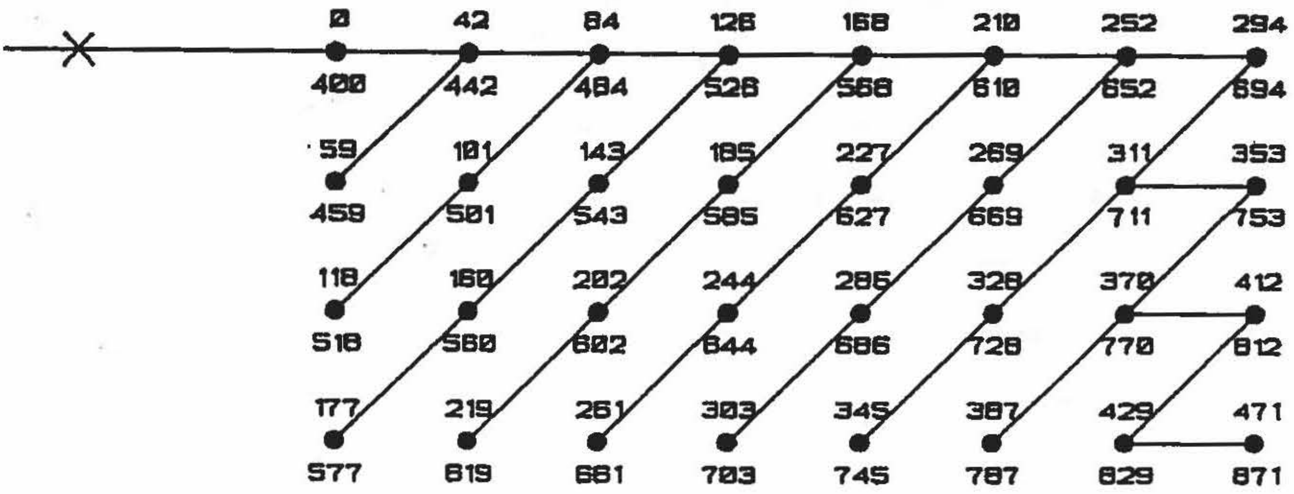
There are a number of non-electric initiation systems available to blasters that make use of some of the same principles discussed in the previous section on detonating cord. However, these systems do not rely on an "exploding cord" which has sufficient energy to detonate any high explosives in conatct with it; they are either "low energy detonating cord", or a plastic "shock tube" with a very small detonation confined inside the plastic tube. Nearly all these systems combine the use of non-electric delay caps and surface delays to create a variety of different delay patterns and delay times. These non-electric caps have various brand names such as "primadet caps", "detaline in-hole delay detonators", "blastmaster millisecond detonators" and have delay times built into them. Because of the wide variety of brands available and the difference between the products, it is imperative that the blaster follow the manufacturer's specific recommendations when using these systems. Both the materials used and the procedures can differ greatly.

In the "nonel" system, for example, the shock wave moves inside the plastic tube acting as the firing signal traveling through the trunklines and downlines. When this firing signal reaches the "non-electric cap," the cap begins to go through its initiation timing sequence and then detonates. In addition to the delays built into the caps, surface delay devices can be connected into the trunkline or between downlines to create timing delays. Since the quantity of the explosive and the detonation signal is so small, there is little noise associated with these systems when compared to a detonating cord shot.

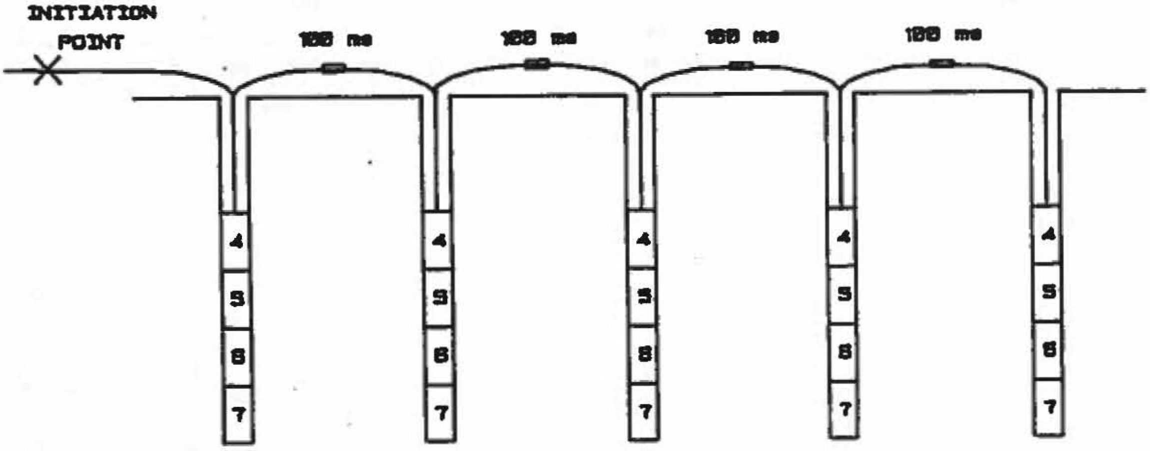
In addition, since it is non-electric the potential for accidental initiation by stray electric currents or radio frequency energy is eliminated. However, this does not mean that non-electric systems are immune to premature detonation by lightening. The heat and pressure of a direct lightning strike will almost certainly initiate a non-electric initiation system. *Therefore, when an thunderstorm approaches, it is mandatory that the blaster take the same precautions with a non-electric shot as he would with an electric shot; that is, he must evacuate the area and prevent access to the blast site.* Most non-electric systems can be initiated or "started" with an electric or safety fuse blasting cap. Obviously, if an electric cap is used to "start" a system, the system is no longer completely non-electric and all precautions regarding stray currents, and radio frequency energy must be observed. To remain completely non-electric, the shot can be fired with a "starter device" designed for this purpose. A typical "starter" is the hand held device that makes use of a shotgun shell primer to initiate a length of nonel tubing inserted into the unit. An example of how a non-electric system delay pattern works is shown in the following example. A non-electric millisecond delay cap with a delay time of 400 ms is used in the primer of every borehole. Both 42 ms and 17 ms trunkline delays are connected between holes as shown.



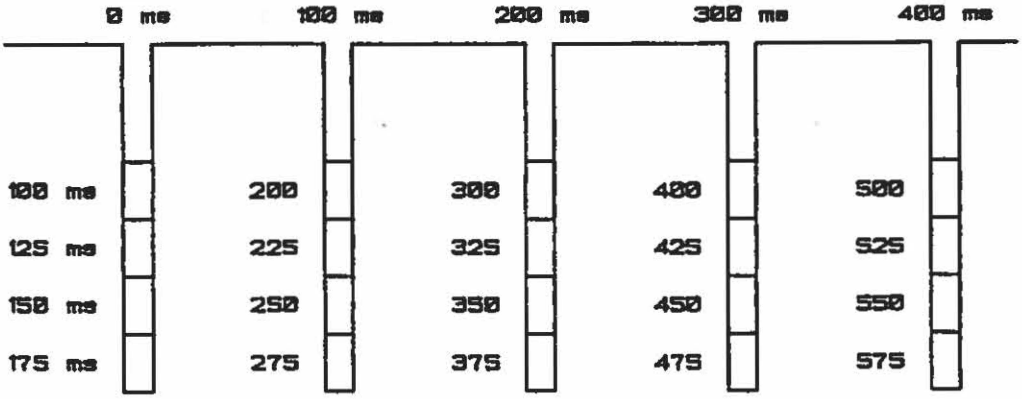
In the following diagram, the number above the borehole shows the surface firing time of each downline entering the borehole, the number below the borehole is simply 400 ms later, which reflects the addition of the in-hole cap delay to the surface firing time of the downline. A close examination of this diagram and the previous one will illustrate how the delay time progresses from the initiation point down the trunkline to each borehole.



These non-electric patterns are also useful in decking applications. For example, consider five boreholes with four deck charges in each one. The bottom deck of each hole has a 175 ms (# 7) nonelectric delay cap, the second deck from the bottom has a 150 ms (# 6) cap, the third deck has a 125 ms (# 5) cap, and the top deck has a 100 ms (# 4) delay cap in it. A 100 ms delay connector is inserted between the boreholes connecting them. The pattern would look like the following.

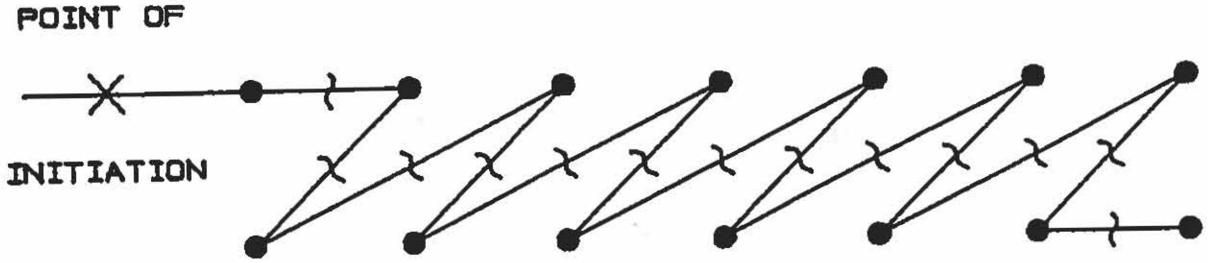


When the shot is fired, the delay times for each deck charge would be as shown in the following diagram.

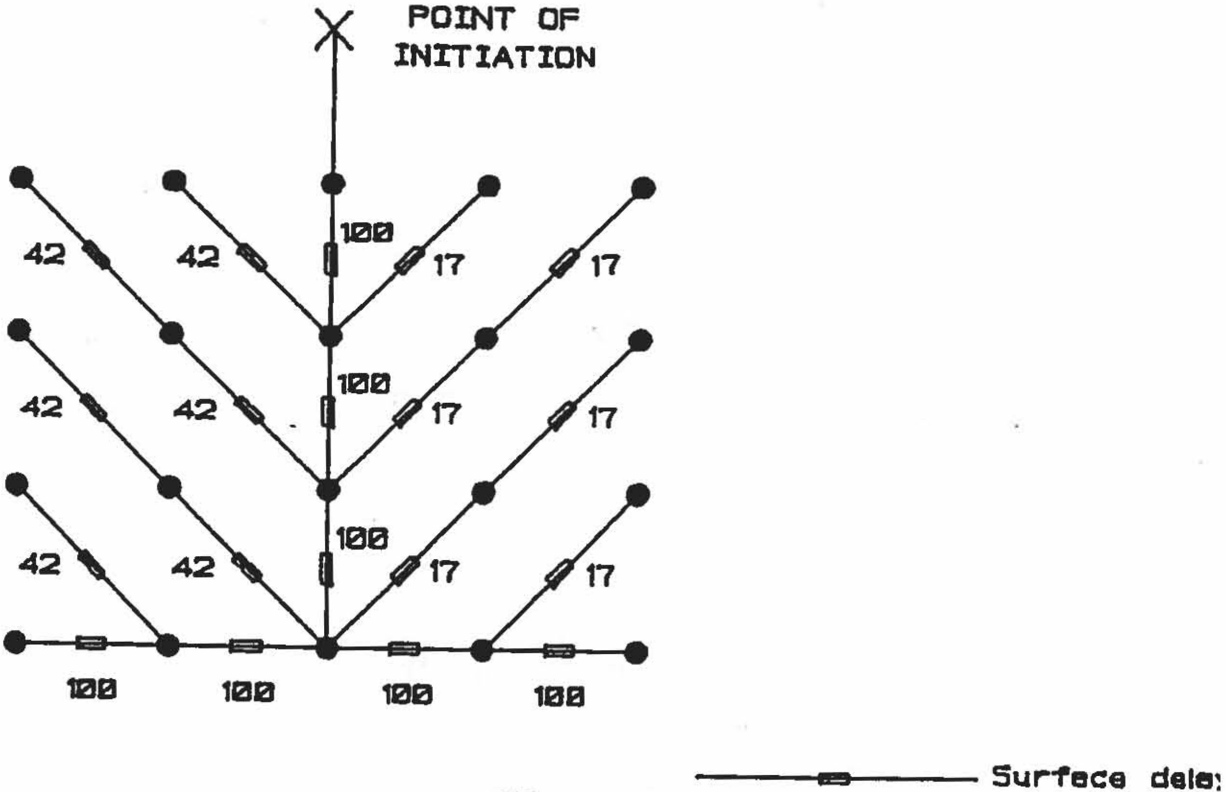


This pattern could be adapted very easily to include a greater or lesser number of deck charges and an indefinite number of boreholes with every charge still in a separate delay interval. However the blaster should be aware that when blasting with this method using a large number of holes, the time duration of the shot will be extended. A shot similar to the one above but with one hundred holes will continue to detonate for 10 seconds. Blasting in this manner, while legal, may cause a large number of public complaints since the ground vibrations will last for this same time.

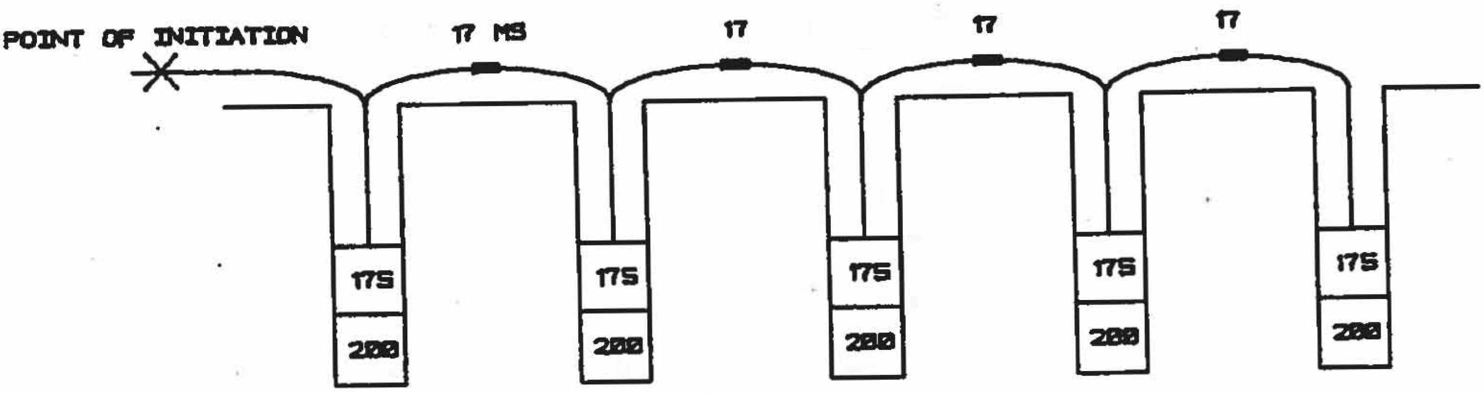
Problem 68: A blasting delay pattern is laid out with a 100 ms non-electric cap in each borehole. A 17 ms surface delay is used to connect the holes to each other as shown. What is the firing time of each borehole? How many holes are firing in any 8 ms period?



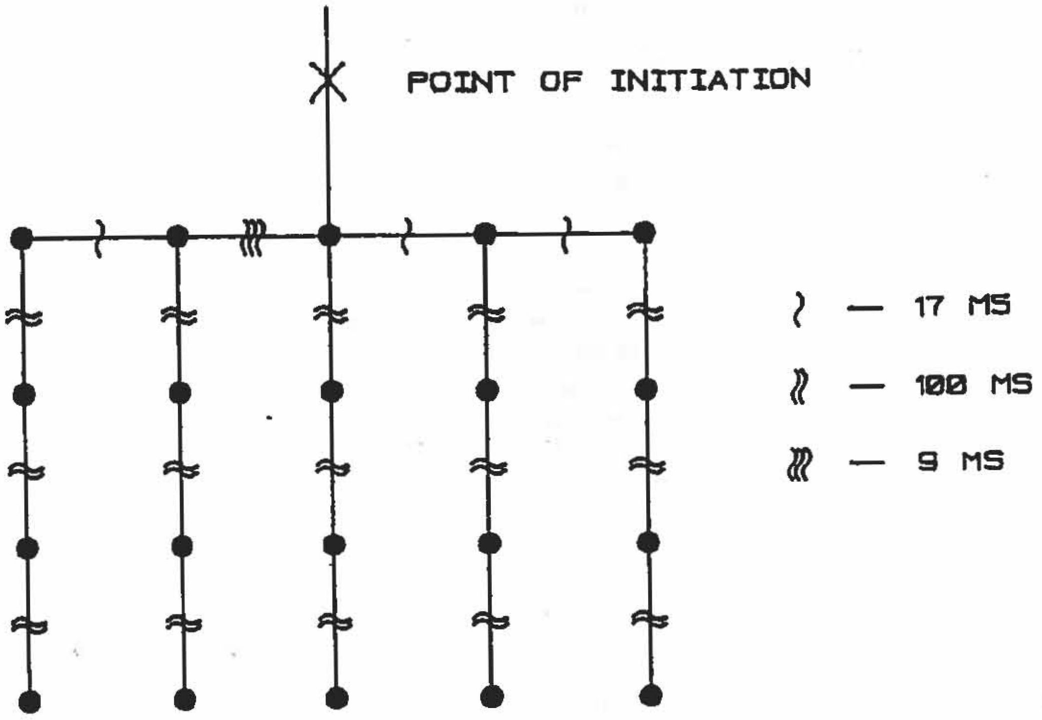
Problem 69: A blasting pattern with 20 holes is initiated with non-electric delay system using surface delays of 17 ms, 42 ms, and 100 ms as shown in the diagram below. Each borehole is primed with a non-electric delay cap having a 400 ms delay. What is the firing time of each borehole? How many holes are fired in any one 8 ms delay period?



Problem 70: A single row of holes is fired non-electrically with two decks per hole. All boreholes are loaded so that the top deck is primed with a 175 ms delay and the bottom deck has a 200 ms delay. A 17 ms surface delay is connected from hole to hole. What is the firing time of each deck in all of the holes?



Problem 71: A trench blast is loaded with 4 rows of 5 holes each and 35 lb of explosives per deck. Each borehole has three decks in it with the bottom deck primed with 300 ms non-electric cap, the middle deck has a 250 ms delay cap, and the top deck has a 200 ms delay. The surface delays consist of 9 ms, 17 ms and 100 ms as shown in the diagram. What is the firing time of all the decks in this shot? How many lb/delay is detonated in this pattern?



Basic Loading Arithmetic

There are a few other basic calculations with which a blaster must be familiar. These are usually applied mathematics such as calculating the weight of a cartridge of explosive or determining how many bags of ANFO are required to load a shot. Some examples of these problems are as follows.

Problem 72: A blaster is loading a small diameter borehole with cartridged explosives. The cartridges he is using are 2" x 8" and there are 60 of these cartridges packed in a 50 pound carton. If the blaster loads 7 of these cartridges in the borehole, how many pounds are loaded in the borehole?

Solution: If 60 cartridges weigh 50 pounds, then each cartridge will weigh 50 lb ÷ 60 cartridges, or 0.83 pounds each.

The blaster is loading 7 of these cartridges per borehole, so the charge weight per borehole is 7 x 0.83 = 5.8 pounds .

Problem 73: A blaster is loading 80 boreholes in a blast and each borehole has 435 pounds of ANFO in it. He is loading from a bulk truck which carries 10000 pounds of premixed ANFO in its bin. How many truckloads will be necessary to load this shot?

Solution: Total explosives = Number of boreholes x pounds per borehole

Total explosives = 80 x 435 = 34800 pounds.

Each truck carries 10000 lbs so it will require 34800 ÷ 10000 or 3½ truckloads to completely load this shot.

Problem 74: A blaster is loading a shot with 50 pound bags of ANFO. There are 42 boreholes in the shot, and all are the same depth. He uses a tape and loads all of them with the same amount of explosives. He uses 189 bags of ANFO to load this shot. How many total pounds of explosives are used in this blast and how many pounds are loaded per borehole?

Total Weight of explosives for shot = 189 bags x 50 lb/bag

Total Weight of explosives for shot = 9450 pounds.

Wt of explosives per hole = Total Weight ÷ Number of holes

Weight of explosives per borehole = 9450 lbs. ÷ 42 = 225 lbs.

Problem 75: A blaster is using gelatin dynamite in 3 inch by 16 inch cartridges. There are 20 cartridges of this explosive in a 50 pound carton. The blaster loads 3 of these cartridges into a 10 foot deep, 3½ inch diameter borehole. He places 3 cartridges in each borehole without tamping or deforming the cartridges. How many pounds of explosives does he load in each hole and how much room is left for stemming?

Problem 76: A blaster drills a shot with 20 boreholes and plans to load each with 180 pounds of ANFO. The ANFO is in 50 pound bags. How many bags are required to load this shot?

Problem 77: A blaster arrives on the bench with a truck carrying 20100 pounds of emulsion explosives. If he plans to load 1675 pounds of emulsion in each borehole, how many boreholes can he load before he has to return to the bin and reload the truck?

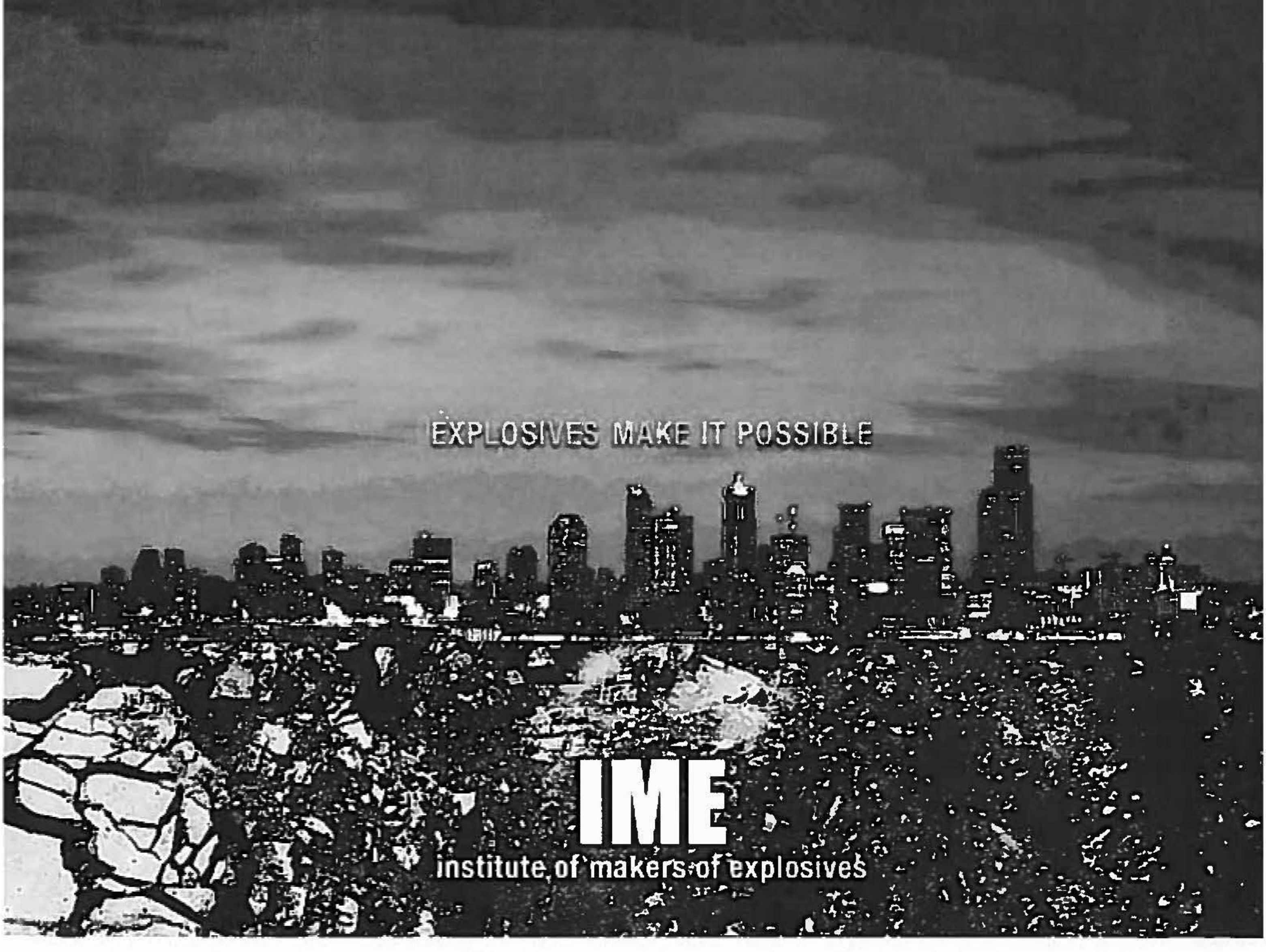
Problem 78: A blaster uses 1¼ x 8 inch sticks of ammonium dynamite. These sticks are packed 110 per 50 pound carton. He places 20 of these sticks under a stubborn tree stump to blast it out of the ground. How many pounds of explosives is he using?

4

SAFETY LIBRARY PUBLICATION

October 2009

WARNINGS AND INSTRUCTIONS FOR CONSUMERS IN TRANSPORTING, STORING, HANDLING AND USING EXPLOSIVE MATERIALS



EXPLOSIVES MAKE IT POSSIBLE

IME

institute of makers of explosives

MEMBER COMPANIES (As of July 2010)

Accurate Energetic Systems
McEwen, Tennessee
Austin Powder Company
Cleveland, Ohio
Baker Hughes
Houston, Texas
Davey Bickford North America
Sandy, Utah
Detotec North America, Inc.
Sterling, Connecticut
Douglas Explosives, Inc.
Philipsburg, Pennsylvania
Dyno Nobel Inc.
Salt Lake City, Utah
General Dynamics – Munitions Services
Joplin, Missouri
GEODynamics, Inc.
Millsap, Texas
IBQ-Britanite
Quatro Barras, Parana, Brazil
Jet Research Center/Halliburton
Alvarado, Texas
Maine Drilling & Blasting
Auburn, New Hampshire
Maxam North America, Inc.
Salt Lake City, Utah
Mineria Explosivos Y Servicios, S.A.
Panama City, Panama
MP Associates, Inc.
Ione, California
Nelson Brothers
Birmingham, Alabama
Nobel Insurance Services
Dallas, Texas
Orica, USA Inc.
Watkins, Colorado
Owen Oil Tools LP
Godley, Texas
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Duenweg, Missouri
Safety Consulting Engineers, Inc.
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SLT Express Way Inc
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Mesa, Arizona
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Titan Specialties, Ltd.
Midlothian, Texas
Tread Corporation
Roanoke, Virginia
Tri-State Motor Transit Company
Joplin, Missouri
Vet's Explosives, Inc.
Torrington, Connecticut
Viking Explosives & Supply, Inc.
Rosemount, Minnesota
W.A. Murphy, Inc.
El Monte, California
Walker's Holdings, Inc.
Red Deer, Alberta, Canada

Associate Status:
Federation of European Explosives Manufacturers
Brussels, Belgium

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The Institute of Makers of Explosives (IME) is the safety association of the commercial explosives industry in the United States and Canada. The primary concern of IME is the safety and security of employees, users, the public, and environment in the manufacture, transportation, storage, handling, use, and disposal of explosive materials used in blasting and other essential operations.

Founded in 1913, IME was created to provide technically accurate information and recommendations concerning commercial explosive materials and to serve as a source of reliable data about their use. Committees of qualified representatives from IME member companies developed this information and a significant portion of their recommendations are embodied in regulations of state and federal agencies.

The Institute's principal committees are: Environmental Affairs; Legal Affairs; Safety and Health; Security; Technical; and Transportation and Distribution.

TABLE OF CONTENTS

SLP-4

Warning and Instructions for Consumers in Transporting, Storing, Handling and Using Explosive Materials

NOTICE

Effective October 1, 1991 (voluntary compliance as of January 1, 1991), many of the U.S. Department of Transportation's (USDOT) proper shipping names and all classifications have been changed for domestic transportation. Although this system is now in effect, there were certain transition dates established to allow a smooth flow into the distribution channels.

The following two charts provide: (1) a comparison of the old and new classifications for explosives; and (2) the transition periods for use of the new names and classifications. When you read through the Institute of Makers of Explosives' (IME) Safety Library Publications (SLPs) please remember to refer to these charts to ensure compliance with applicable regulations:

Chart 1

OLD CLASSIFICATION	CURRENT CLASSIFICATION
Class A Explosives	Division 1.1 or 1.2
Class B Explosives	Division 1.2 or 1.3
Class C Explosives	Division 1.4
Blasting Agents	Division 1.5
(No Applicable Class)	Division 1.6

Chart 2

TRANSITION PERIODS	
1 October 1991	All new explosives must be classified under the new regulations.
1 October 1993	Mandatory compliance with new classification and hazard communication requirements (except placarding).
1 October 1994	Mandatory use of new (UN) placards, except DOT placards may be used for domestic highway transportation. Package manufacturers will only be permitted to make non bulk packaging which meet United Nations performance standards.
1 October 1996	Mandatory use of performance oriented packaging standards (UN) for non bulk packaging.
1 October 2001	Mandatory use of UN placards for all modes of transportation.

DEFINITIONS

See the most recent edition of IME SLP-12, "*Glossary of Commercial Explosives Industry Terms*" for the definition of terms used in this document.

WARNINGS AND INSTRUCTIONS

Warnings and Instructions for Transporting, Storing, Handling, and Using Explosive Materials.

WARNING: READ THIS SLP BEFORE USING ANY EXPLOSIVE MATERIAL

PREVENTION OF ACCIDENTS IN THE TRANSPORTATION, STORAGE, HANDLING, AND USE OF EXPLOSIVE MATERIALS

The misuse of any explosive material can kill or injure you or others.

Prevention of accidents depends on careful planning and the use of proper procedures.

This SLP is designed to help you use explosive materials safely.

GENERAL WARNINGS

All explosive materials are dangerous and must be carefully transported, handled, stored, and used following proper safety procedures or under competent supervision.

ALWAYS follow federal, state, and local laws and regulations.

ALWAYS lock up explosive materials and keep from children and unauthorized persons. See the most recent edition of IME SLP-27 "*Security in Manufacturing, Transportation, Storage and Use of Commercial Explosives*" for comprehensive recommendations for security.

ALWAYS maintain an accurate inventory of the contents of each magazine.

ALWAYS discontinue operations during the approach and progress of electrical storms.

ADDITIONAL INFORMATION MATERIALS ON SAFETY OF EXPLOSIVES

The Institute of Makers of Explosives publishes a number of publications on safety. Refer to page 24 of this SLP for a complete list.

EXPLOSIVE MATERIALS COVERED IN THIS SLP

High Explosives and Permissible Explosives
Electronic, Electric, and Nonelectric Detonators
Safety Fuse
Detonating Cord
Blasting Agents
Slurries, Water Gels, and Emulsions
Primers and Boosters

QUESTIONS ON THE USE OF EXPLOSIVE MATERIALS

These warnings and instructions cannot cover every situation which might occur. If you have any questions on the use of an explosive material, contact your supervisor or the manufacturer.

LOST OR STOLEN EXPLOSIVES

Call the Bureau of Alcohol, Tobacco, Firearms and Explosives (BATF) 24-hours a day at 1-800-800-3855 or at the lost or stolen explosives number 1-888-282-2662.

STORING EXPLOSIVE MATERIALS

LOCATION OF MAGAZINES

ALWAYS separate magazines from other magazines, inhabited buildings, highways, and passenger railways. See IME Safety Library Publication No. 2, *American Table of Distances* or seek approval on a risk basis as determined by IMESAFR from the authority having jurisdiction.

ALWAYS post normal access roads to explosive storage magazines with the following warning sign:

DANGER!
NEVER FIGHT EXPLOSIVE FIRES
EXPLOSIVES ARE STORED ON THIS SITE
CALL (Emergency phone number)

(This sign shall be weather resistant with a reflective surface
and lettering at least 2" (50 mm) high. The first two lines shall be
in red lettering and the remaining printing in black).

NEVER allow combustible material to accumulate within 25 feet (8.3 meters) of the magazine.

NEVER allow any lighters, matches, open flame, or other sources of ignition or volatile materials within 50 feet (16.6 meters) of the magazine.

NEVER attempt to make any repairs to the inside or outside of a magazine containing explosive materials.

CONSTRUCTION OF MAGAZINES

ALWAYS be sure magazines are solidly built and securely locked in accordance with federal regulations, to protect from weather, fire, and theft. Protect from penetration by bullets and missiles, as required by the classification of the explosive material.

ALWAYS keep the inside of the magazine clean, dry, cool, and well ventilated.

ALWAYS post clearly visible "EXPLOSIVES – KEEP OFF" signs outside of the magazine. Locate signs so that a bullet passing directly through them cannot hit the magazine.

CONTENTS OF MAGAZINES

ALWAYS clean up spills promptly. Follow manufacturer's directions.

ALWAYS store only explosive materials and other approved blasting materials and accessories in a magazine.

ALWAYS rotate stocks of explosive materials so the oldest material in the magazine is used first. Consult with the manufacturer to assure that the recommended storage time for the explosive materials is being followed.

NEVER store detonators with other explosive materials.

NEVER use explosive materials which seem deteriorated. Before using, consult your supervisor or the manufacturer.

NEVER exceed recommended storage conditions and temperatures for explosive materials. Check with your supervisor or the manufacturer.

NEVER perform any type of operation in a magazine other than inspection, inventory, or bringing in or taking out explosive materials.

TRANSPORTING EXPLOSIVE MATERIALS

ALWAYS keep matches, lighters, open flame, and other sources of ignition at least 50 feet (16.6 meters) away from parked vehicles carrying explosive materials.

ALWAYS follow federal, state, and local laws and regulations concerning transportation.

ALWAYS load and unload explosive materials carefully.

NEVER park vehicles containing explosive materials close to people or congested areas.

NEVER leave a vehicle containing explosive material unattended.

HANDLING EXPLOSIVE MATERIALS

GENERAL

ALWAYS use permissible explosive materials in flammable, gassy, or dusty atmospheres when required by applicable federal, state, and local laws and regulations.

ALWAYS keep explosive materials away from children, unauthorized persons and livestock.

ALWAYS discontinue operations during the approach and progress of electrical storms.

NEVER use explosive materials unless completely familiar with safe procedures or under the direction of a qualified supervisor.

NEVER handle explosive materials during the approach of an electrical storm. Find a safe location away from the explosive materials. When a storm is approaching, consult your supervisor. This applies to both surface and underground operations.

NEVER fight fires involving explosive materials. Remove yourself and all other persons to a safe location and guard the area.

NEVER put explosive materials in the pockets of your clothing.

PACKAGING

ALWAYS	close partially used packages of explosive materials.
ALWAYS	store explosives in their original package.
NEVER	touch metal fasteners with metal slitters when opening packages of explosive materials.
NEVER	mix different explosives in the same package.
NEVER	remove explosive material from its package unless designed to be used in that manner.

PROTECTING EXPLOSIVE MATERIALS

ALWAYS	insure that there are no foreign objects, loose powder, or moisture in a fuse detonator before inserting the safety fuse.
ALWAYS	avoid the use of "shot breaks" to prevent premature initiation or damage of the initiation system. If "shot breaks" must be used, all loaded holes should be considered in determining the size of the blast site and blast area.
NEVER	insert anything into a fuse detonator except safety fuse.
NEVER	use explosive materials that have been water soaked, even if they now appear to be dried out.
NEVER	investigate the contents of a detonator.
NEVER	pull wires, safety fuse, shock tube, coupling device, plastic tubing, or detonating cord out of any detonator or delay device.
NEVER	take apart, or alter the contents of any explosive materials.
NEVER	expose explosive materials to sources of heat exceeding 150 degrees Fahrenheit (F) or to open flame, unless such materials or procedures for their use have been recommended for such exposure by the manufacturer.
NEVER	strike explosive materials with, or allow them to be hit by, objects other than those required in loading.
NEVER	subject explosive materials to excessive impact or friction.
NEVER	allow loaded firearms in the vicinity of, nor shoot near, explosive materials, magazines or vehicles loaded with explosive materials.

USING EXPLOSIVE MATERIALS: Drilling, Loading, and Tamping

GENERAL

ALWAYS keep accurate and complete records of all blasts. Blast records shall include, but not necessarily limited to, the names of the blaster-in-charge and crew, the exact blast site location, blast hole drill logs, weather conditions, site-specific loading information, geologic data, , vibration compliance data, a sketch of the blast site including nearest structures if applicable, shot design details with individual charge timing, and the blaster's signature. Refer to SLP 3 and SLP 27 for further shot report recommendations.

ALWAYS use proper fall protection devices, and or, systems when working closer than 6 feet (2 meters) to the crest of a high-wall, or if there is any danger of falling.

ALWAYS wear proper floatation devices, and or, fall protection if working closer than 6 feet (2 meters) to the crest or in an area that presents a risk of falling into water.

DRILLING

ALWAYS provide adequate training and education for drillers to ensure the safe operation of equipment and safety of drillers.

ALWAYS check for unfired explosive materials on surface or face before drilling.

ALWAY ensure drill equipment is in proper working order and all safety devices are in place prior to drilling.

ALWAYS ensure leveling jacks, measurement devices, and tools for proper drill setup on stable ground are in working order, and used, to provide control of drill and pattern designs.

ALWAYS utilize drill logs to record adequate information for proper loading of every bore hole.

ALWAYS ensure noise and dust protection equipment and devices are in place prior to operation.

NEVER drill into explosive materials, or into a bore hole that has contained explosive materials.

NEVER start a drill hole in a bootleg.

NEVER begin drilling operations until adequate site preparation has been done for the type of drill being used to ensure the safe movement and operation.

NEVER begin drilling until the blast pattern design is properly laid out and bore hole locations are adequately marked for the drill.

NEVER drill angle holes unless measurement equipment and controls are in place to ensure correct borehole placement, location, and end direction.

LOADING

ALWAYS inspect the highwall, crest, and open face conditions before loading.

ALWAYS check each borehole to assure it is safe for loading.

ALWAYS load the face holes in such a manner that you can see the crest at all times.

ALWAYS take precautions during pneumatic loading to prevent the accumulation of static electric charges.

NEVER place any parts of the body in front of the borehole except those required for the loading, tamping, or stemming operations.

NEVER force explosive materials into a borehole.

NEVER load a borehole containing hot or burning material. Temperatures above 150° F could be dangerous.

NEVER spring a borehole near other holes loaded with explosive materials.

NEVER stack more explosive materials than needed near working areas during loading.

NEVER drop large diameter, rigid cartridges [4 inch (102 mm) or larger] directly on the primer.

TAMPING

NEVER tamp a primer or explosive material removed from its cartridge.

NEVER tamp explosive materials with metallic devices, except jointed non-sparking poles with nonferrous metal connectors.

NEVER tamp violently.

NEVER kink or damage safety fuse, detonating cord, shock tube, plastic tubing, coupling devices, or wires of detonators when tamping.

USING EXPLOSIVES MATERIALS: General Instructions for Primers

GENERAL

NEVER prepare more primers than immediately needed.

ALWAYS prepare primers just prior to their immediate deployment into the blast hole and as close to time of loading explosives to ensure proper placement, limiting damage to, and effective priming of the explosive column

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

NEVER slit, drop, twist or tamp a primer.

PREPARING THE PRIMER

ALWAYS insert the detonator completely into a hole in the explosive material made with a non-sparking punch designed for that purpose, or in the cap well of a manufactured booster.

ALWAYS secure the detonator within the primer.

ALWAYS point the detonator in the direction of the main explosive charge.

ALWAYS secure the detonator to a primer cartridge so that no tension is placed on the leg wires, safety fuse, shock tube, plastic tubing, or detonating cord at the point of entry into the detonator.

ALWAYS be certain the detonator is fully inserted in the primer cartridge or booster and does not protrude from it.

ALWAYS use cartridges and/or boosters that are physically compatible with the specific detonator design.

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 or attempt to force a detonator into explosive material.

LOADING THE BOREHOLE

ALWAYS use the first cartridge in the borehole as the primer cartridge where two inch diameter or smaller cartridges are used.

NEVER drop large diameter, rigid cartridges [4 inch (102 mm) or larger] directly on the primer.

MAKING PRIMERS WITH ELECTRIC OR ELECTRONIC DETONATORS

SMALL DIAMETER CARTRIDGES (Less than four inches (102 mm) in diameter) – Figure 1

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.

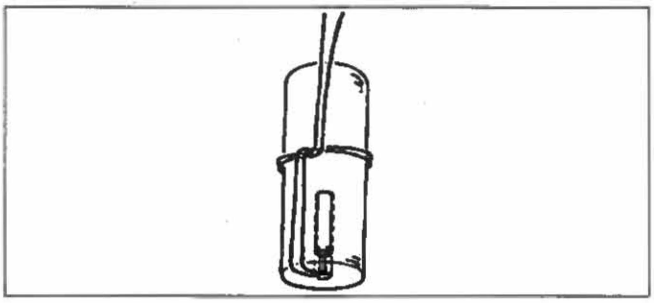

Figure 1: Recommended method of making primer with small diameter cartridge and electric or electronic detonators.

LARGE DIAMETER CARTRIDGES (Four inches (102 mm) and larger in diameter) – Figure 2

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 (306 mm) 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 into this hole, and take up all the slack in the wires.

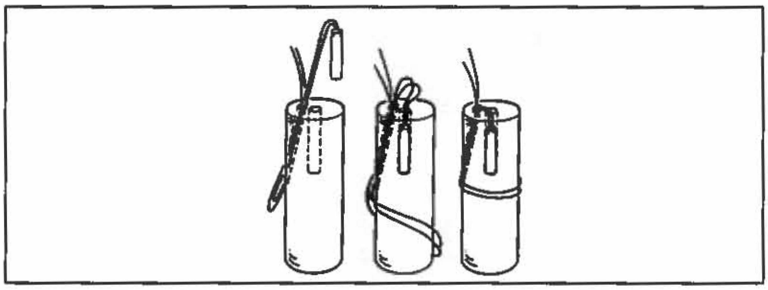

Figure 2: Recommended method of making primer with large diameter cartridge and electric or electronic detonators.

CAST BOOSTERS – Figure 3

ALWAYS	follow the manufacturer's recommendation for the attachment and use of detonators with cast or manufactured boosters.
NEVER	thread safety fuse through the inside of a cast booster.
ALWAYS	use two safety fuse assemblies (double prime) when the primer is used as a primary explosive charge and exposure to personnel from subsequent misfire retrieval activity is a potential.

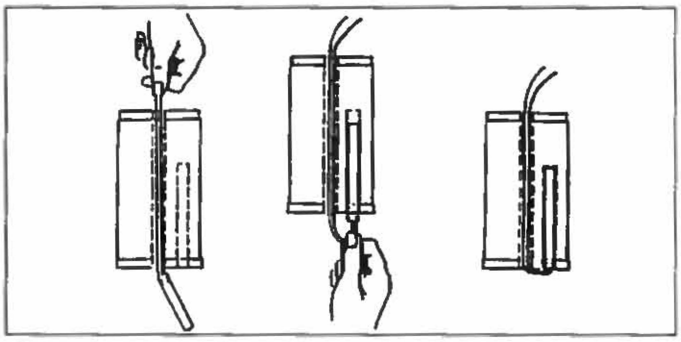

Figure 3: Recommended method of making primer with cast booster and non-electric, electric or electronic detonators.

PLASTIC FILM CARTRIDGES – Figure 4

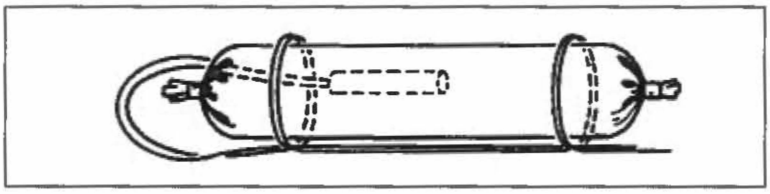

Figure 4: Recommended method of making primer with plastic film cartridge and electric or electronic detonators.

MAKING PRIMERS WITH FUSE OR NONELECTRIC DETONATORS

SIDE PRIMING METHOD – Figure 5

Step 1: Punch a hole in the side of the cartridge. Make the hole deeper than the length of the detonator and pointed downward rather than across the cartridge.

Step 2: Insert the detonator.

Step 3: Tape the safety fuse, shock tube, or plastic tubing to the cartridge to prevent the detonator from being pulled out of the cartridge.

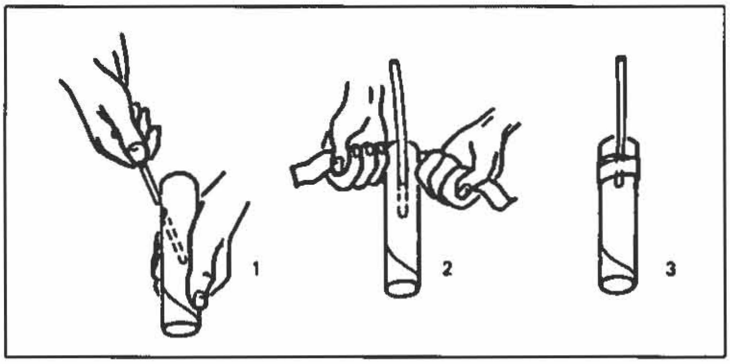

Figure 5: Recommended method of making primer using the side priming method.

REVERSE PRIMING METHOD – Figure 6 and Figure 7

Step 1: Punch a hole straight into one end of the cartridge. Make the hole deeper than the length of the detonator.

Step 2: Insert the detonator.

Step 3: Fold back the fuse, shock tube, or plastic tubing over the end so that it lies along the length of the cartridge.

Step 4: Tape the fuse, shock tube, or plastic tubing to the cartridge.

CAUTION: If miniaturized detonating cord is used, the explosives must be insensitive to initiation by the detonating cord for this method to work.

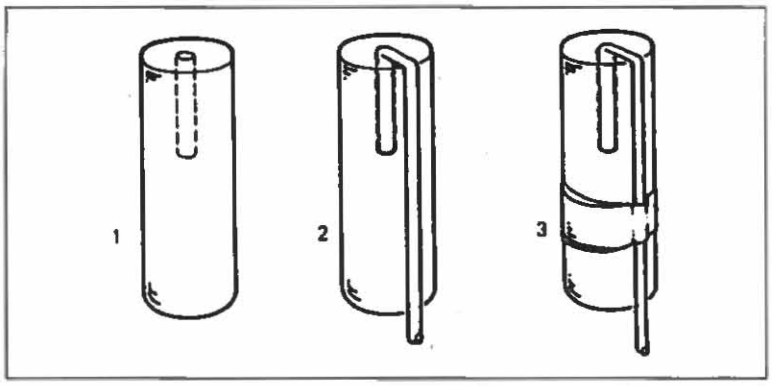

Figure 6: Recommended method for making primer by reverse priming method.

PLASTIC FILM CARTRIDGE PRIMER – Figure 7

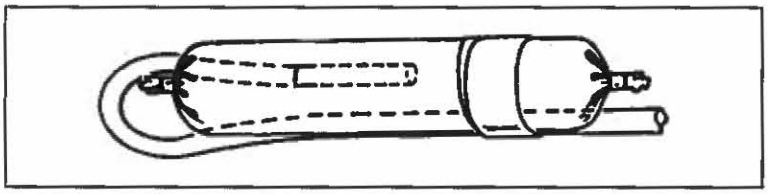

Figure 7: Recommended method of making primer with plastic film cartridge and fuse or nonelectric detonator.

MAKING PRIMERS WITH DETONATING CORD

DETONATING CORD WITH CAST BOOSTERS – Figure 8

ALWAYS follow manufacturer's recommendations for using detonating cord with cast or manufactured boosters.

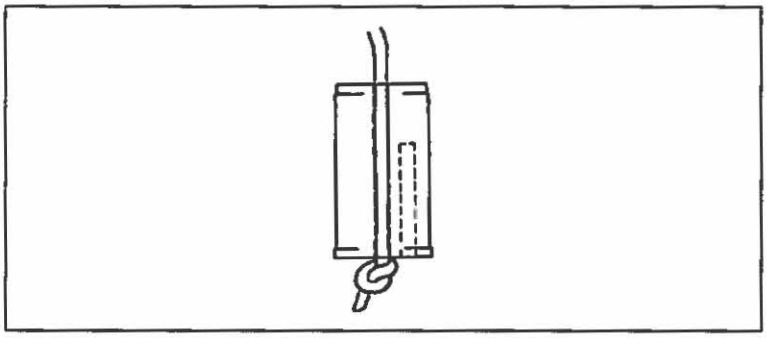

Figure 8: Recommended method for making primer with cast booster and detonating cord.

MISCELLANEOUS TYPES OF PRIMERS

ALWAYS follow manufacturer's recommendations for preparation of primers not covered elsewhere in these recommendations.

USING EXPLOSIVE MATERIALS: General Precautions

PROTECTING YOURSELF

ALWAYS keep explosive materials away from food, eyes, or skin. Flush areas of contact with large quantities of water.

ALWAYS avoid exposure to excessive noise from blasting. Comply with federal, state, and local laws and regulations.

ALWAYS fire the shot from a position outside the blast area (away from where flyrock might occur), or if necessary to be in the blast area, from an adequate blast shelter that provides protection from flying material.

ALWAYS remain in a position away from the blast area until post-blast fumes, dusts, or mists have subsided.

NEVER handle any explosive materials or position yourself near any explosive materials when initiating a blast.

NEVER fire the shot from in front of the blast.

NEVER breathe dust or vapors from explosive materials.

PROTECTING OTHERS

ALWAYS clear the immediate area of persons.

ALWAYS post guards to prevent access to the blast area.

ALWAYS sound adequate warning prior to the blast.

ALWAYS use a blasting mat or other protective means when blasting close to residences or other occupied buildings or other locations where injury to persons or damage to property could occur as a result of flyrock.

NEVER fire a blast without a positive signal from the person in charge.

NEVER permit anyone to handle explosive materials or position themselves near explosive materials when a blast is to be initiated.

PROTECTING THE BLAST AREA

ALWAYS clear the immediate area of vehicles, equipment, and extra explosive materials.

ALWAYS design a blast to avoid excessive air blast, ground vibration, and flyrock. Comply with federal, state, and local laws and regulations.

ALWAYS clear the blast area of all personnel prior to testing the circuit when using a blasting machine that is a combination firing unit and circuit tester.

NEVER allow any source of ignition within 50 feet (16.6 meters) of a blast site except approved safety fuse lighters.

USING EXPLOSIVE MATERIALS: Electric Initiation

PREPARING THE ELECTRIC BLASTING CIRCUIT

ALWAYS test the circuit for continuity and proper resistance, using a blasting galvanometer or an instrument specifically designed for testing electric detonators and circuits containing them.

ALWAYS fire electric detonators with firing currents in the range recommended by the manufacturer.

ALWAYS keep electric detonator wires or lead wires disconnected from the power source and shunted until ready to test or fire.

ALWAYS keep the firing circuit completely insulated from ground or other conductors.

ALWAYS be sure that all wire ends are clean before connecting.

NEVER use any instruments, such as electrician's meters, that are not specifically designed for testing blasting circuits or detonators. Such meters produce sufficient electrical energy to prematurely initiate electric detonators which can result in injury or death.

NEVER mix electric detonators made by different manufacturers in the same circuit.

NEVER mix electric detonators of different types in a circuit, even if made by the same manufacturer, unless such use is approved by the manufacturer.

NEVER use aluminum wire in a blasting circuit.

NEVER make final hookup to power source until all personnel are clear of the blast area.

NEVER mix electric detonators and electronic detonators in the same blast, even if these are made by the same manufacturer, unless such use is approved by the manufacturer.

NEVER use test equipment and blasting machines that are designed for electronic detonators with electric detonators.

PROTECTING AGAINST EXTRANEOUS ELECTRICITY

ALWAYS check for stray current.

ALWAYS check surrounding area near the blast site for the presence of fixed and mobile sources of radio frequency fields including cellular phones, handheld transceivers, driver monitoring systems, etc, and comply with the recommended safe distance tables in SLP-20.

NEVER load boreholes in open work near electric power lines unless the firing lines and detonator wires are anchored or are too short to reach the electric power lines.

NEVER handle or use electric detonators;

a) when stray currents are present,
b) during electrical storms,
c) if static electricity is present.

NEVER use electric detonators (electric blasting caps) near radio-frequency transmitters unless in accordance with IME Safety Library Publication No. 20, "*Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Electric Detonators (Blasting Caps).*"

NEVER use electric detonators near RF sources unless in accordance withSLP-20 or an "RF safe" detonator is used. Consult the manufacturer of the detonator for additional assistance.

NEVER have electric power wires or cables near electric detonators or other explosive materials except at the time and for the purpose of firing the blast.

NEVER open blasting machines or handle batteries near electric detonators.

USING EXPLOSIVE MATERIALS: Detonating Cord Initiation

ALWAYS use a detonating cord matched to the blasting methods and type of explosive materials being used.

ALWAYS handle detonating cord as carefully as other explosive materials.

ALWAYS cut the detonating cord downline from the spool before loading the rest of the explosive material into a blast hole or beginning any other tie-in activity.

ALWAYS cut the detonating cord trunkline from the spool immediate following completion of the tie-in activities.

ALWAYS use a sharp knife, razor blade, or instrument designed for cutting detonating cord.

ALWAYS make tight connections, following manufacturer's directions.

ALWAYS attach detonators to detonating cord with tape or methods recommended by the manufacturer.

ALWAYS point the detonators toward the direction of detonation – Figure 9.

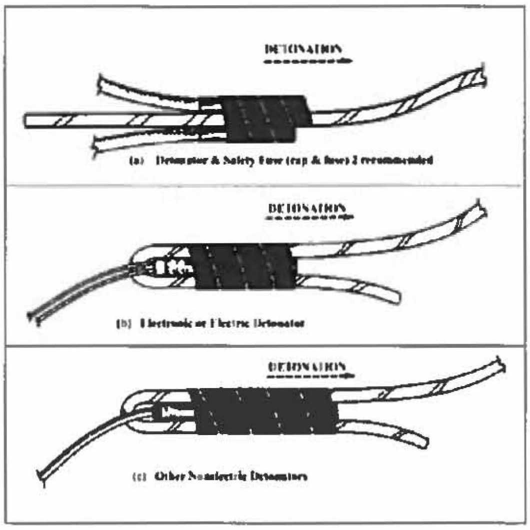

Figure 9: Methods for attaching detonators to detonating cord

ALWAYS attach the cord initiating detonator at least six inches from the cut end of the detonating cord.

ALWAYS use a suitable booster to initiate wet detonating cord.

ALWAYS use surface delay connectors designed for use with detonating cord.

NEVER make loops, kinks, or sharp angles in the cord which might direct the cord back toward the oncoming line of detonation.

NEVER damage detonating cord prior to firing.

NEVER attach detonators for initiating the blast to detonating cord until the blast area has been cleared and secured for the blast.

NEVER use damaged detonating cord.

NEVER cut detonating cord with devices such as scissors, plier-type cutters, cap crimpers, or similar instruments.

USING EXPLOSIVE MATERIALS: Nonelectric Initiation

GENERAL

ALWAYS follow manufacturer's warnings and instructions, especially hookup procedures and safety precautions.

NEVER hold nonelectric leads during firing. This may cause injury or death.

NEVER use tubing or detonating cord leads for any purpose other than that specified by the manufacturer.

MINIATURIZED DETONATING CORD SYSTEM

ALWAYS use explosives that are insensitive to initiation by the miniaturized detonating cord.

NEVER join two sections of miniaturized detonating cord. A detonation will not pass through such a connection.

SHOCK TUBE SYSTEM

ALWAYS insure that shock tubing connections to detonating cord are at right angles to prevent angle cut-offs.

ALWAYS avoid situations where initiation system components can become entangled in machines, equipment, vehicles, or moving parts thereof.

ALWAYS lead shock tube to the hole in a straight line and keep it taut.

ALWAYS follow the manufacturer's recommendations when cutting and splicing lead-in trunkline shock tube.

ALWAYS unhook surface delay connectors prior to handling a misfire.

ALWAYS protect surface delay connectors from unintended energy sources such as: impact from falling rock, impact from tract vehicles or other mobile equipment, drilling equipment, flame, friction, electrical discharge from power lines, static electricity, and lightning.

NEVER drive any vehicles over shock tube.

NEVER tie together two lengths of shock tubing. An initiation signal will not pass through a knotted connection.

NEVER pull, stretch, kink, or put tension on a shock tube such that the tube could be caused to break or otherwise malfunction.

NEVER hook-up any surface delay connector before you are ready to fire the blast.

NEVER hook-up a surface delay connector to its own shock tube.

NEVER leave an unhooked surface delay connector in close proximity to the shock tube of a loaded blast hole.

NEVER remove the detonator from a surface delay connector block.

NEVER attempt to initiate detonating cord with a surface delay connector designed for the initiation of shock tube only.

USING EXPLOSIVE MATERIALS: Electric Initiation

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 detonator system integrity prior to initiation of blast.

ALWAYS keep the firing circuit completely insulated from ground or other conductors.

ALWAYS use the wires, connectors and coupling devices specified by the manufacturer.

ALWAYS follow the manufacturer's instructions when aborting a blast. Wait a minimum of 30 minutes before returning to a blast site after aborting a blast unless the manufacturer provides other specific instructions.

ALWAYS clear the blast area of personnel, vehicles and equipment prior to hooking up to the firing device or blast controller.

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 instructions for system hook-up for electronic detonators.

ALWAYS follow manufacturer's recommended practices to protect electronic detonators from electromagnetic, RF, or other electrical interference sources.

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

ALWAYS ensure the blaster in charge has control over the blast site throughout the programming, system charging, firing, and detonation of the blast.

ALWAYS use extreme care when programming delay times in the field to ensure correct blast designs. Incorrect programming can result in misfires, flyrock, excessive air overpressure, and vibration.

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.

NEVER attempt to use blasting machines, testers, or instruments with electronic detonators that are not specifically designed for the system.

NEVER attempt to cut and splice leads unless specifically recommended by the manufacturer.

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

NEVER load boreholes in open work near electric power lines unless the firing lines and detonator wires are anchored or are too short to reach the electric power lines.

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.

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.

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

USING EXPLOSIVE MATERIALS: Fuse Detonator and Safety Fuse Initiation

GENERAL

ALWAYS handle fuse carefully to avoid damaging the covering. In cold weather, warm fuse slightly before using to avoid cracking the water-proofing.

ALWAYS know the burning speed of the safety fuse by conducting a test burn of the fuse in use to make sure you have time to reach safety after lighting.

ALWAYS "double cap" safety fuse assemblies if they are being used as the primary explosive charge, or when initiating detonating cord for firing a blast.

NEVER use lengths of safety fuse less than three feet.

NEVER insert anything but safety fuse in the open end of fuse-type detonator.

NEVER use fuse which has been kinked, bent sharply, or handled roughly in such a manner that the powder train may be interrupted.

NEVER attempt to disarm, or relight, a safety fuse assembly once the unit has been lit or attempted to be lit, until the misfire waiting period has passed.

STEPS FOR ASSEMBLING FUSE DETONATOR AND FUSE

Step 1: Wait until you are ready to insert fuse into fuse detonators before cutting it.

Step 2: Cut off an inch or two to insure a dry end.

Step 3: Measure correct length of fuse from roll and cut squarely across with a fuse cutter designed for this purpose; not a knife.

Step 4: Visually inspect inside of detonator for foreign material or moisture; if wet or if foreign matter cannot be removed by pouring, do not use the detonator. Dispose of detonator 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.

ALWAYS cut off an inch or two to insure a dry end. Cut fuse squarely across with the proper tool designed for this purpose; not a knife.

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

ALWAYS insure that the detonator is securely crimped to the fuse.

ALWAYS use waterproof crimp or waterproof the fuse-to-detonator joint in wet work.

ALWAYS use cap crimpers to crimp to 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 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.

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

LIGHTING SAFETY FUSE

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.

Single-fuse ignition hot wire lighters, pull-wire lighters or thermalite connectors.

Multiple-fuse ignition igniter cord with thermalite connectors.

ALWAYS light fuse with a fuse lighter designed for the purpose.

ALWAYS use the "buddy system" when lighting safety fuse – one lights the fuse, the other times and monitors.

NEVER light fuse until sufficient stemming has been placed over the explosive to prevent sparks from coming into contact with the explosive.

NEVER drop or load a primer with a lighted safety fuse into a borehole.

NEVER use matches, cigarette lighters, cigarettes, pipes, cigars, carbide lamps, or other unsafe means to ignite safety fuse.

USING EXPLOSIVE MATERIALS: After-Blast Procedures

DISPOSAL OF EXPLOSIVE MATERIALS

ALWAYS treat deteriorated or damaged explosive materials with special care. They may be more hazardous than explosive materials in good condition.

ALWAYS dispose of explosive materials using proper methods. Check with your supervisor or the manufacturer. If the manufacturer is not known, check with an IME member company listed in the front of this booklet.

NEVER reuse any explosive material packaging.

NEVER burn explosive materials packaging in a confined space.

MISFIRES

ALWAYS deal with misfires of electronic detonator systems in accordance with the manufacturer's recommended procedures. (Electronic detonator systems may vary widely in design and application).

ALWAYS wait at least 30 minutes with fuse detonator misfires and at least 15 minutes with electric and other nonelectric detonator misfires, unless the manufacturer recommends otherwise, before returning to the blast area. Comply with federal, state, and local laws and regulations.

ALWAYS wait a minimum of 30 minutes with electronic detonator misfires unless the manufacturer recommends additional time before returning to the blast area.

ALWAYS shunt the bare wires of a misfired electric detonator by twisting them together and taping them to the metal shell to protect against extraneous sources of electrical energy.

ALWAYS consider using air or water to remove stemming from a charged bore hole where nonelectric or electronic initiation systems have been used before considering using a vacuum removal system alternative.

NEVER drill, bore, or pick out any explosive materials that have been misfired. Misfires should only be handled by a competent experienced person knowledgeable of the blast design, including the location and type of all explosive materials.

NEVER use a vacuum removal system such as a vacuum truck, "shop vac", or vacuum cleaner to remove stemming from any bore hole in which electric detonators have been used.

BLAST-GENERATED FUMES

ALWAYS assume toxic fumes are present from all blasts or burning explosive materials and stay away until they have dissipated.

ALWAYS assume toxic concentrations of carbon monoxide gas from heavily confined shots such as those used in trenching can migrate through the earth and accumulate in nearby underground enclosed spaces such as basements or manholes.

ALWAYS comply with applicable federal, state, and local laws and regulations for safe fume levels before returning to blast area.

REDUCING POST-BLAST FUME HAZARD

ALWAYS monitor nearby enclosed spaces for toxic gasses such as carbon monoxide after blasting.

ALWAYS ventilate nearby enclosed spaces and continue to monitor them if any carbon monoxide gas is detected in the enclosed space after blasting.

ALWAYS excavate blasted material from heavily confined shots as soon as possible. Blasted material may harbor dangerous concentrations of carbon monoxide gas for days if not excavated.

ALWAYS use the largest diameter cartridge that fits the job.

ALWAYS use water resistant explosive materials in wet conditions, and fire the blast as soon as practicable after loading.

ALWAYS spray the muckpile with water in accordance with federal, state, and local laws and regulations.

ALWAYS avoid conditions that might cause explosive materials to burn rather than detonate.

NEVER enter a recently blasted trench or an enclosed space without checking for toxic gasses such as carbon monoxide.

NEVER use explosive materials that appear deteriorated or damaged.

NEVER use more explosive material than necessary.

NEVER add combustible materials to the explosive material load.

NEVER use combustible materials for stemming.

USING EXPLOSVE MATERIALS: Seismic Prospecting

ALWAYS secure explosive material at a safe depth in the borehole. Use shot anchors when needed.

ALWAYS secure any casing that might blow out of the borehole.

ALWAYS place the detonator and/or primer near the top of the explosive column, in the side or in the cap well of one of the top two cartridges.

NEVER approach explosive material thrown out of the borehole by an explosion until you are sure that it is not burning.

NEVER drop a seismic charge containing the primer cartridge.

IME SAFETY LIBRARY

IME's Safety Library is comprised of 15 publications which address a variety of subjects pertaining to safety and its application to the manufacture, transportation, storage, handling, and use of commercial explosive materials. Many of the industry recommendations set forth in these Safety Library Publications (SLPs) have been adopted by federal, state, and local regulatory agencies.

The following SLPs comprise the Safety Library:

SLP 1	Construction Guide for Storage Magazines (Sept 2006)
SLP 2	The American Table of Distances (June 1991)
SLP 3	Suggested Code of Regulations (October 2009)
SLP 4	Warning and Instructions for Consumers in Transporting, Storing, Handling and Using Explosive Materials (October 2009)
SLP 12	Glossary of Commercial Explosives Industry Terms (Feb 2007)
SLP 14	Handbook for the Transportation and Distribution of Explosive Materials (April 2007)
SLP 17	Safety in the Transportation, Storage, Handling and Use of Explosive Materials (March 2007)
SLP 20	Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Commercial Electric Detonators (July 2001)
SLP 22	Recommendations for the Safe Transportation of Detonators in a Vehicle with Certain Other Explosive Materials (Feb 2007)
SLP 23	Recommendations for the Transportation of Explosives Division 1.5, Ammonium Nitrate Emulsions, Division 5.1, Combustible Liquids, Class 3, and Corrosives, Class 8 in Bulk Packagings (Feb 2010)
SLP-24	Recommendations for Handling 50 Metric Tons or More of Commercial Division 1.1 or 1.2 Break-Bulk Explosives Materials in Transportation at Commercial Facilities in the United States
SLP 25	Explosives Manufacturing & Processing Guideline to Safety Training (June 2006)
SLP 27	Security in Manufacturing, Transportation, Storage and Use of Commercial Explosives (Jan 2005)
SLP 28	Recommendations for Accountability and Security of Bulk Explosives and Bulk Security Sensitive Materials
SLP-29	Recommendations for the Environmental Management of Commercial Explosives (Environmental SLP)

Cost data and purchasing instructions are available from the IME office:

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Washington, DC 20036-3605
Phone (202) 429-9280
www.ime.org
info@ime.org

NOTES

NOTES

IMESAFR

INSTITUTE OF
MAKERS OF
EXPLOSIVES

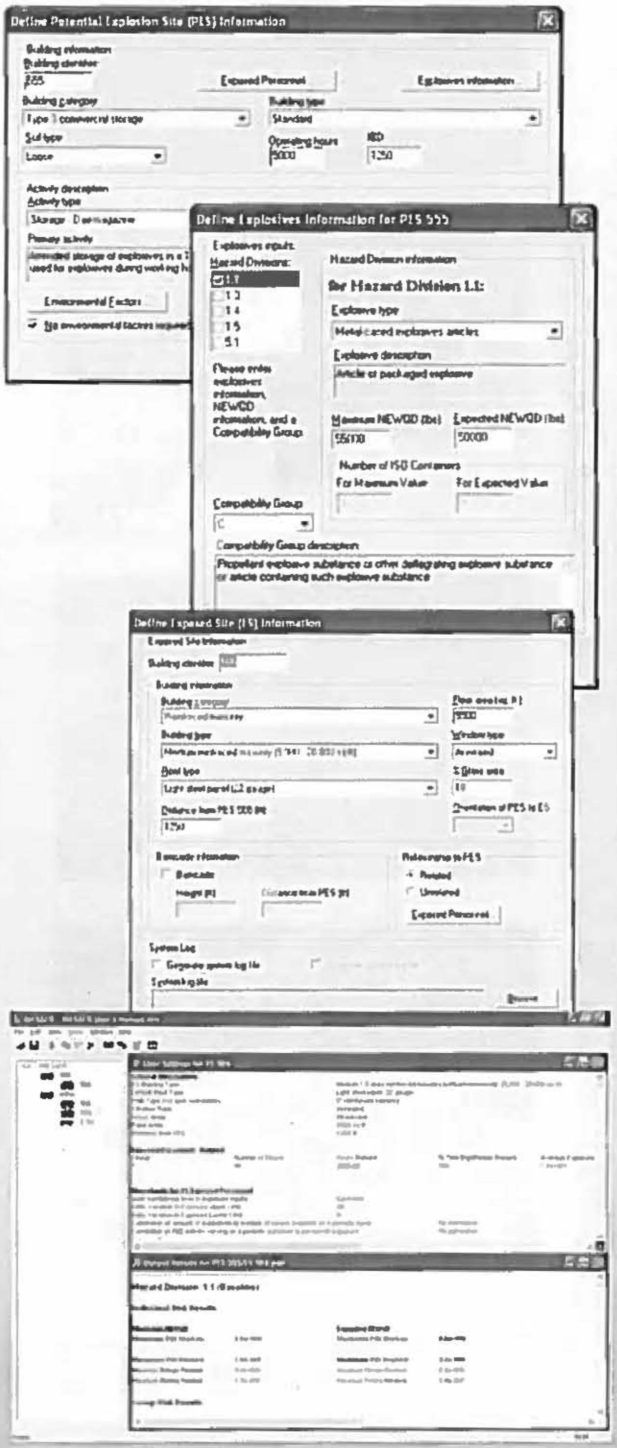
A-P-T Research, Inc.

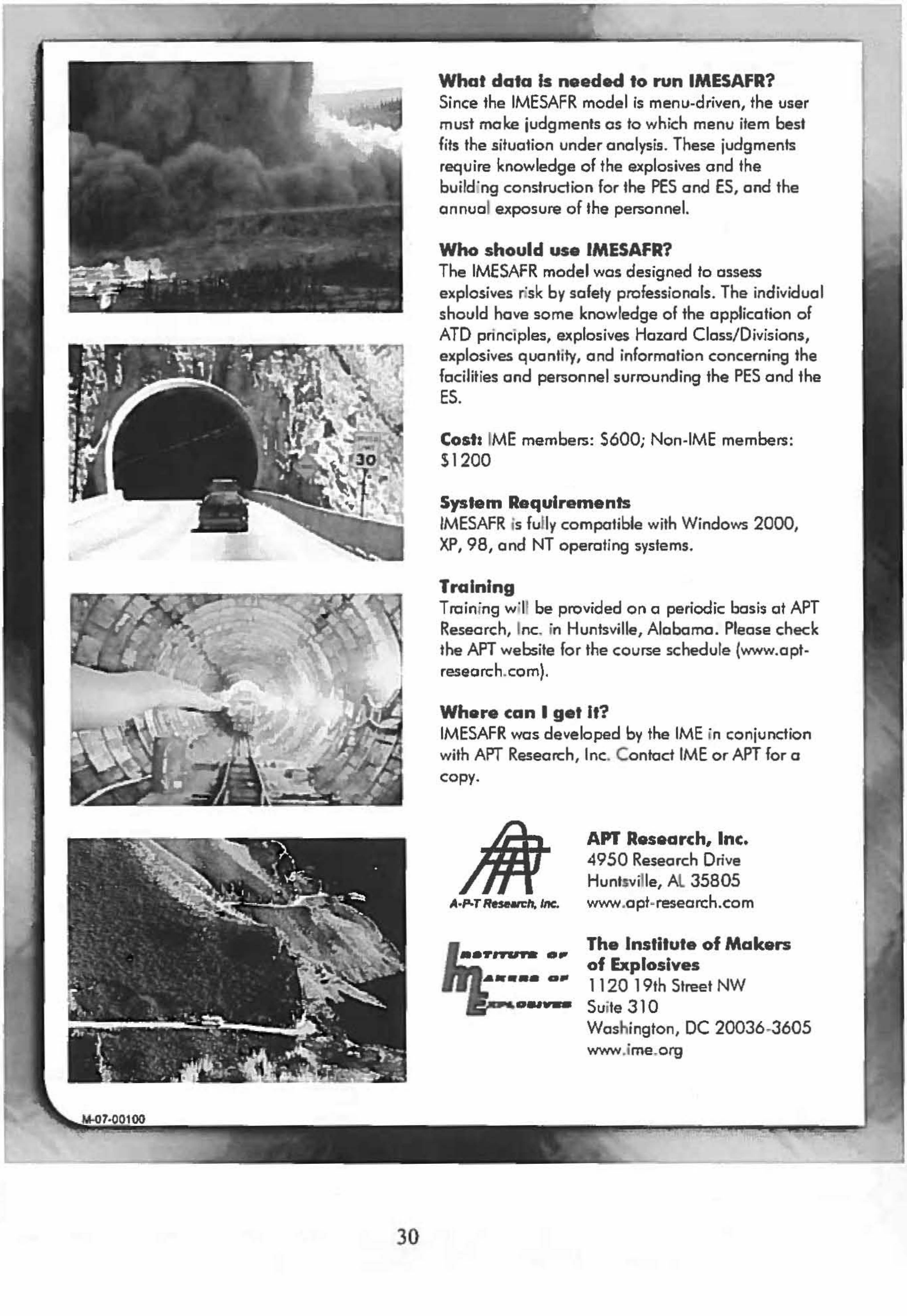
What is IMESAFR?

Institute of Makers of Explosives Safety Analysis for Risk (IMESAFR) is a probabilistic risk assessment tool used to calculate risk to personnel from explosives facilities. This tool is a supplement to the longstanding American Table of Distances. Whereas the ATD provides a level of safety based on explosives quantity and distance, IMESAFR determines a level of safety based upon risk. In addition to explosives quantity and distance, IMESAFR uses the donor structure, the activity at the donor, and the structure of the exposed sites to determine the level of safety.

Why was IMESAFR developed?

IMESAFR was developed to provide a more comprehensive assessment of the overall risk of explosives operations. The commercial explosives industry in the United States uses the ATD as the basis for safe siting of explosives storage facilities. ATD siting involves the evaluation of a specific magazine and inhabited building or public highway, which are referred to as a Potential Explosion Site (PES) / Exposed Site (ES) pair in IMESAFR. This evaluation yields the recommended separation distance based on the quantity of explosives involved and whether a barricade exists. Although the same criteria can be applied to explosives manufacturing operations, the ATD was intended for use in limited permanent storage situations. In addition to permanent storage situations, IMESAFER accounts for other activities such as manufacturing, assembly, and loading and unloading.





What data is needed to run IMESAFR?

Since the IMESAFR model is menu-driven, the user must make judgments as to which menu item best fits the situation under analysis. These judgments require knowledge of the explosives and the building construction for the PES and ES, and the annual exposure of the personnel.

Who should use IMESAFR?

The IMESAFR model was designed to assess explosives risk by safety professionals. The individual should have some knowledge of the application of ATD principles, explosives Hazard Class/Divisions, explosives quantity, and information concerning the facilities and personnel surrounding the PES and the ES.

Cost: IME members: $600; Non-IME members: $1200

System Requirements

IMESAFR is fully compatible with Windows 2000, XP, 98, and NT operating systems.

Training

Training will be provided on a periodic basis at APT Research, Inc. in Huntsville, Alabama. Please check the APT website for the course schedule (www.apt-research.com).

Where can I get it?

IMESAFR was developed by the IME in conjunction with APT Research, Inc. Contact IME or APT for a copy.

A-P-T Research, Inc.

APT Research, Inc.
4950 Research Drive
Huntsville, AL 35805
www.apt-research.com

Institute of Makers of Explosives

The Institute of Makers of Explosives
1120 19th Street NW
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Washington, DC 20036-3605
www.ime.org

M-07-00100

DESTRUCTION OF COMMERCIAL EXPLOSIVE MATERIALS

At times it may be necessary to destroy commercial explosive materials. These may consist of explosives or blasting agents from containers that have been broken during transportation or may be materials that have exceeded their recommendation shelf life or are believed to be overage or are no longer needed.

Due to the many developments in explosive technology over the past few years, the appearance and characteristics of products have undergone marked changes. To be sure that you are familiar with the properties of the product that you plan to destroy, the manufacturer of that product should be consulted for the most current product information and the recommended method of disposal and/or destruction.

The member companies of the Institute of Makers of Explosives have agreed to supply advice and assistance in destroying explosives. If the manufacturer is known, seek his assistance. If the manufacturer is not known, a member company of the Institute of Makers of Explosives may provide advice or assistance.

The above policy of IME member companies related only to commercial explosive materials. It does not include handling improvised explosive devices or bombs, military ordnance, military explosives, or homemade explosive materials.

IME member companies also cannot become involved in destroying explosive materials, which have been used for illegal purposes, are reportedly stolen property or are considered as evidence in any potential civil litigation or criminal prosecution.

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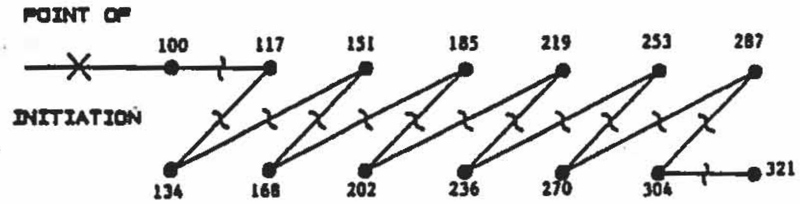
ANSWERS TO UNSOLVED PROBLEMS

4. 52.5 ohms
5. 53.2 ohms
6. 88.4 ohms
8. 0.38 ohms
9. .105 ohms
12. 15.33 ohms
13. 33.7 ohms
14. 6.0 ohms
18. 3.0 ohms
19. 3.19 ohms
20. 15.91 ohms
23. 6.67 amps
24. 325 volts
25. 8 amps
28. 5.8 amps
29. 7.3 amps
31. No, each cap receives only 0.43 amps.
35. 300 yds^3
36. 22.2 yds^3
37. 1225 yd^3
42. 1.22 lb/yd^3
43. 1.38 lb/yd^3
44. 0.71 lb/yd^3
45. 1.04 lb/yd
46. 120 lbs.
47. 24 lbs.
48. 45511 lbs.
51. 265 lbs.
52. 781 lbs.
53. 146.7 lbs.
57. 625 lbs.
58. 25 lbs.
59. 1 hole.
60. 4 holes.
61. 8 lbs.
65. Maximum of 3 holes/delay.
66. #0 interval = 100 lb/delay.
    #1 interval = 200 lb/delay.
    #2 interval = 300 lb/delay.
    #3 interval = 300 lb/delay.
    #4 interval = 200 lb/delay.
    #5 interval = 100 lb/delay
67. Maximum 375 lb/delay.

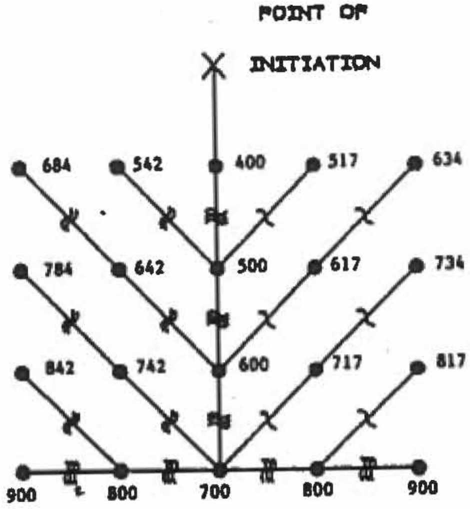
68. SEE THE NEXT PAGE FOR
69. THE ANSWERS TO THESE
70. NONELECTRIC PROBLEMS
71.

75. 7.5 lb/hole, 6 ft. stemming
76. 72 bags
77. 12 holes
78. 9.09 lb.

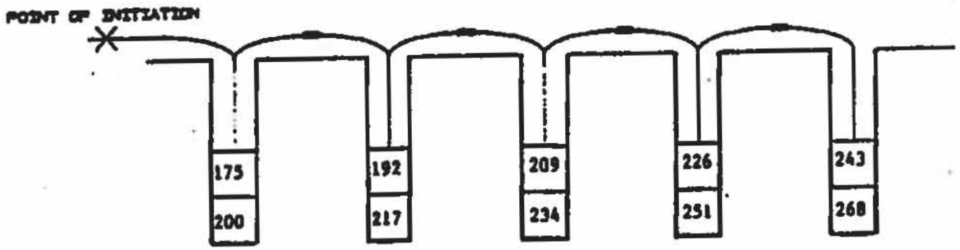
68. 1 hole per delay



69. 2 holes per delay



70.



71. 70 lb/delay