EXPLOSIVES HANDBOOK

for

ACCIDENT PREVENTION

March, 2001

PREMATURE BLASTING INCIDENTS

1. LIGHTNING

Each year in the United States lightning strikes kill about 100 people and cause injury to many more. Mining activities are especially susceptible to lightning hazards because these activities occur in open areas. When an electrical storm occurs people generally seek shelter from the wind, rain and hail rather than lightning. Some types of structures such as enclosed metal vehicles, i.e. automobiles provided good protection from rain and lightning. Special precautions are required when handling explosive materials when an electrical storm is approaching. Evacuation is generally required because it is not generally practical to provide protection in time at the place where protection is needed. Electric detonators, <u>when connected in a blasting circuit</u> are highly susceptible to premature initiation by lightning whether shunted or unshunted. The initiation mechanisms include induction in a closed (shunted) circuit, stray current through areas of damaged insulation or bare wire in contact with the earth near strike and direct strike. All explosives materials including nonelectric initiation systems are susceptible to initiation by a direct lightning strike or a fire caused by a lightning strike. When an electrical storm is in progress or approaches within about five miles, good practice dictates that mine site areas containing explosive materials should be evacuated. It has been determined that thunder is not generally audible beyond eight miles; however, it could be less depending upon the terrain and wind conditions. In the absence of lightning detection instrumentation, the approach of a storm can be approximated by measuring the elapsed time between a lightning flash and the sound of thunder. <u>Sound takes approximately five seconds to travel each mile</u>. Explosives storage areas should also not be entered during an electrical storm.

2. EXTRANEOUS ELECTRICITY

Extraneous electricity is electrical energy, other than actual firing current, which may be a hazard when using electric detonators. Extraneous electricity includes stray current, static electricity, radio frequency energy and capacitive or inductive coupling. Lightning, normally included under extraneous electricity, is covered under its own heading in this report. Some procedures for minimizing extraneous electricity hazards at operations using electric blasting are contained in National Safety Council Data Sheet 644 (1974).

IMPACT

The impact sensitivity of explosive materials varies widely. In general, all cap sensitive products are more impact sensitive than products classed by The Department of Transportation as blasting agents. Within a given classification, nitroglycerin-based products, including dynamites and gelatins, are generally more impact sensitive than slurry, emulsion and water gel compositions. However, it is the detonators, whether electric or nonelectric, that are the most impact sensitive of commercially used explosive products. Virtually all detonators used in mining contain highly sensitive primary explosive compositions which make them impact sensitive. The impact sensitivity of surface delay detonators is somewhat reduced by the use of plastic coverings. Some products, such as detonating cord, are not highly impact sensitive so long as the outer covering remains intact. The PETN explosive by itself, however, is highly sensitive to impact. The impact sensitivity of these products is controlled by the outer covering material and perhaps the core load. Most, but not all, of the impact incidents that occur in mining result from undetected misfired explosives.

INCIDENTS CAUSED BY OTHER BLASTING HAZARDS

MISFIRES

A misfire is the complete or partial failure of any blasting material to explode as planned. Misfires are a serious safety hazard and may be costly to remove. The occurrence of misfires should indicate to an operator that problems exist. Misfire prevention pays large dividends in safety and economy. It may be a problem with the timing of a newly designed blast pattern, a change in geology or some procedural change with loading or hookup. Is the new initiation system compatible with products being used? Is the priming adequate? Is there a problem with cutoffs, wet AN-FO or damage to downlines while stemming? Is the blasting crew adequately trained? The causes of misfires may be complex. If misfires are not a rare occurrence, it is strongly suggested that the operator request assistance in solving misfire problems from the explosives supplier or manufacturers representative, a blasting consultant or regulatory authority. At some operations misfires may be a common occurrence. They are usually not reportable events under 30 CFR Part 50.10 unless an ignition occurs. Federal regulations require that faces and muckpiles shall be examined for undetonated explosives materials following each blast. Misfires shall be reported to the supervisor and disposed of in a safe manner before other work is performed in that blasting area. Misfire disposal is hazardous and should be carried out only by experienced personnel who are familiar with the hazards of the products involved. Accurate product and loading information is essential when misfire removal is required.

Drilling into misfired explosive material is the most common cause of misfire related mining accidents. Other leading causes are improper disposal and impact during the mucking operation.

4. ELEVATED TEMPERATURE/MINIMUM AND MAXIMUM USE TEMPERATURE

Elevated temperature incidents include those involving burning explosive material, either with or without detonation. The source may be localized from a cause such as welding or involve a larger area such as a heated kiln or a fire.

High temperatures may also be generated by the chemical reaction of ANFO blasting agent with certain pyrite ores. When reaction occurs, the loaded holes may become sufficiently hot to cause the auto ignition of detonators and burning of explosive materials. When these problems occur they must be treated on a site specific basis. Solutions to a problem may include one or more of the following:

A) Use an explosive material other than AN-FO that is compatible with the field conditions.

B) Modify the AN-FO blasting agent mixture by adding small quantities of urea or zinc oxide. The resulting mixture must be carefully controlled, tested and monitored to insure product reliability under the conditions of use.

C) The rock may be hot or reactive to the product or both. The use of bagged explosive material will be beneficial in reactive areas, but may not be suitable for some hot areas, depending on the bagging material.

D) Other changes include the use of a stemming material other than the drill cuttings, elimination of the detonator in the hole and top priming using detonating cord.

E) Loaded holes in hot or reactive material should be initiated without delay.

Storage

The useful life of a product is determined from its composition, packaging and conditions of storage. Two important factors that affect the storage life of explosive materials are humidity and temperature. For most products storage at 0 to 90°F is acceptable if the location is ventilated. Temperature sensitive explosives materials, stored at a low temperature, must be allowed to reach the manufacturers recommended minimum use temperature prior to detonation. The manufacturer should be consulted about storage requirements and product shelf life.

Use

Some explosives materials, generally emulsions and water gels, become insensitive at temperatures below about 40° F. Manufacturers recommendations should be closely followed when using temperature sensitive products near minimum or maximum use temperatures. At low temperatures explosive materials may become less sensitive and fail to detonate. At elevated temperatures auto ignition (especially with detonators) may occur. What is the highest temperature that explosives products function reliably? The Institute of Makers of Explosives recommends that boreholes should not be loaded when the temperature exceeds 150°F, unless the explosives materials and procedures used have been recommended for such (See IME publication, SLP 4, Warnings and Instructions).

2. LATE FIRING (HANGFIRES)

Blasters should be aware that late firings or hangfires may occur when electric detonators are supplied with too much firing current. A firing current greater than about 10 amperes from an uninterrupted source will likely initiate arcing in an ordinary commercial electric delay detonator. This situation causes an arcing malfunction in the detonator. Arcing occurs because the detonator receives more electrical energy than it can easily dissipate. When arcing occurs the detonator shell is ruptured and the delay element is bypassed. This condition is very dangerous because either a misfire or a late firing at some undetermined time up to several minutes later results. Fortunately, the problem can be easily eliminated by either using a capacitive discharge blasting machine or using a suitable means to limit the firing current. The author is not aware of any recent arcing incidents that have occurred with electric detonators. However, some late firings that were product related have occurred with a nonelectric initiation system.

Four incidents involving defective in-hole delay elements of the Dupont

4. CONCUSSION AND FLYROCK

Almost every blast has some material movement which might be called flyrock. 3
Flyrock is a major cause of injury and death in mining. For the purposes of this discussion we shall define three zones associated with rock movement.

<u>Concussion Zone</u>: This is a close-in area that is affected by rock and shock waves. The probability of a very serious or fatal injury to an unprotected person in this area is extremely high.

<u>Normal Flyrock Zone</u>: This is the area where flyrock is expected. It is the 4
protected blast area of a shot beyond the concussion zone. Shelter is required for all persons remaining in this area when blasting occurs.

<u>Excessive Flyrock Zone</u>: This is the zone where flyrock projected beyond the protected blast area. Flyrock does not reach this area in a normal blast. Flyrock reaches this area due to abnormal drilling, loading or undetected geological conditions.

ABSTRACT OF INVESTIGATION

Date: December 21, 1999

Slide Number: 21 (Fatal Case Number: 53)

Accident Classification: Explosives and Breaking Agents

Type of Mine: Limestone - Surface

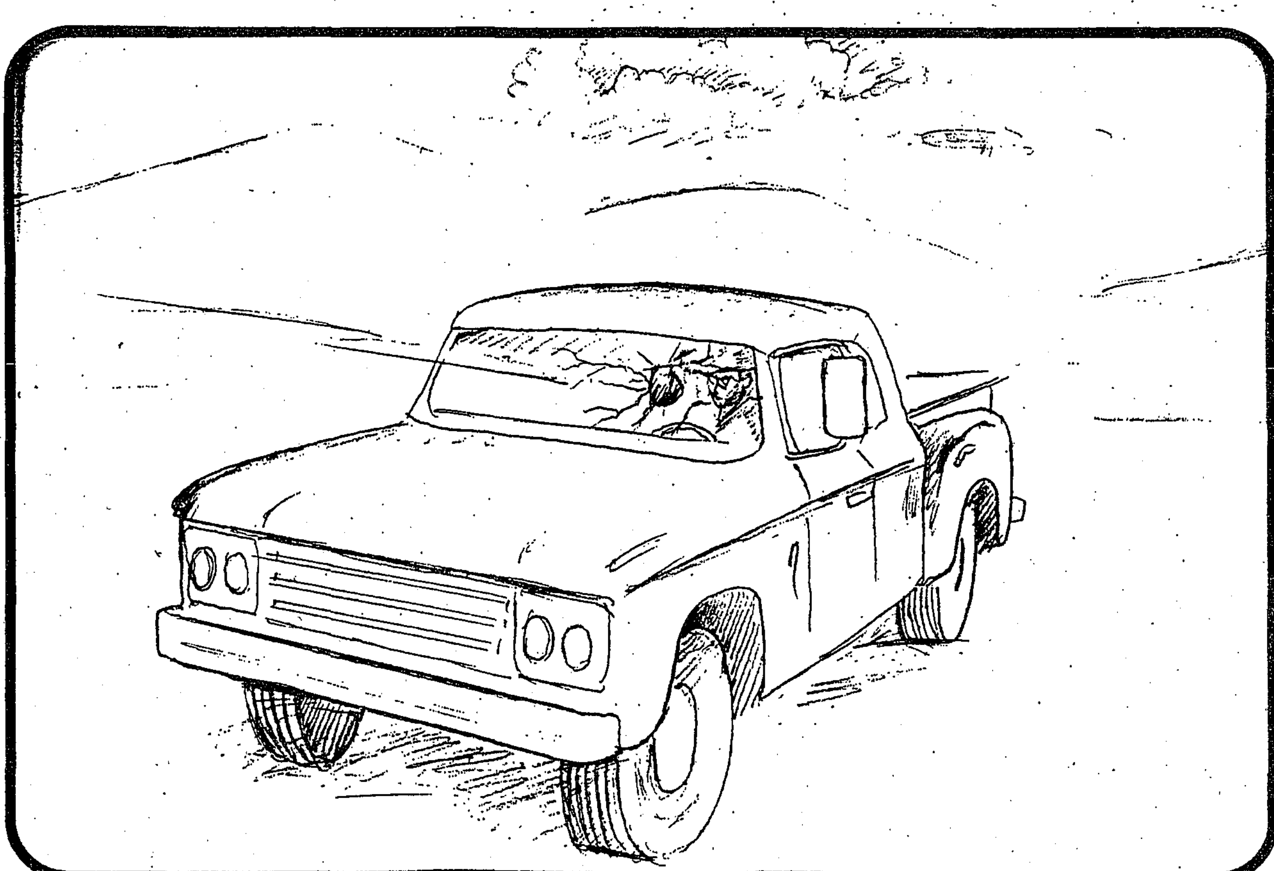
Location: Pennsylvania

Age of Victim: 32
Total Mining Experience: 7 years
Job Classification: Equipment Operator
Number Employed at Mine: 13

An equipment operator was sitting in a pickup truck guarding a road leading to a blasting site. Soon after a shot was detonated, a baseball-sized piece of flyrock entered the cab through the windshield causing fatal injuries.

Best Practices:

- Blast patterns should be designed, drilled, and loaded in a manner that minimizes flyrock.
- Blasts should not be initiated until the blast area has been safely determined and all persons have been evacuated from the designated area.



Citation 2 Item 1 Type of Violation: **Serious**

T8 CCR 1565 Handling and Use of Explosive Materials.

(j) Loaded holes shall not be left unattended.

On 04/09/98, a misfire of one hole containing approximately 880 pounds of explosive with an unfired booster and cap occurred. The licensed blaster in charge and the general contractors Safety Department were aware of the condition. The misfire was not addressed and re-blasted until 04/16/98. Between these dates, the loaded hole was left unattended as verified by management and safety personnel. Production in the pit area continued as usual for five days and nights.

Date By Which Violation Must be Abated:	04/21/98	ABATED
Proposed Penalty:	$ 2340.00	

INFORMAL CONFERENCE AVAILABLE
CONTACT MINING & TUNNELING OFFICE
LISTED ON CITATION

Citation 4 Item 1 Type of Violation: Serious

T8 CCR 1566 Blasting Signals

(b) Prior to firing of a shot, all persons in the danger area shall be warned of the blast and be ordered to a safe distance from the area. A competent flagger shall be posted at all access points to the danger area.

On 04/16/98, while shooting a misfire, fly rock was cast 2700' and landed in the vicinity of employees. One large rock was cast over the head of an inspector and struck an excavator 1700' from the blast site. Employees were exposed to serious injury.

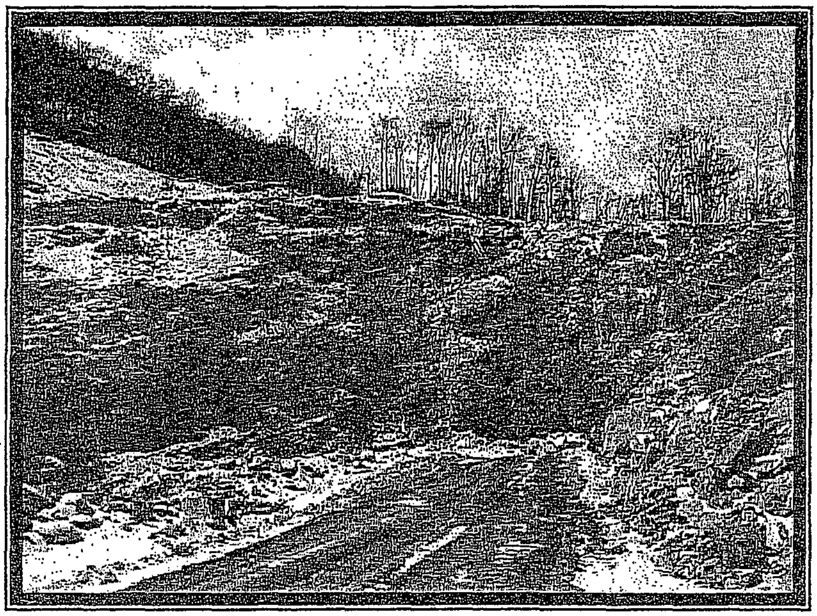
Date By Which Violation Must be Abated:	04/21/98	ABATED
Proposed Penalty:	$ 2340.00	

United States Department of Labor
MSHA
Mine Safety and Health Administration

Fatalgram

J. Davitt McAteer
Assistant Secretary for
Mine Safety and Health

METAL/NONMETAL MINE FATALITY - On January 27, 2000, a 49-year-old dr 11-1/2 years mining experience was fatally injured at a crushed stone operation victim had positioned his truck-mounted drill parallel to the edge of the highwall preparation for drilling. The stabilizers were lowered and as the drill mast was b raised, one of the stabilizers sank into the ground causing the drill to overturn. fell over the highwall edge, crushing the operator's cab.



Best Practices

- Persons experienced in identifying loose ground should examine highwal prior to work beginning and as conditions warrant during the shift.
- Drills should not be positioned parallel to highwall edges.

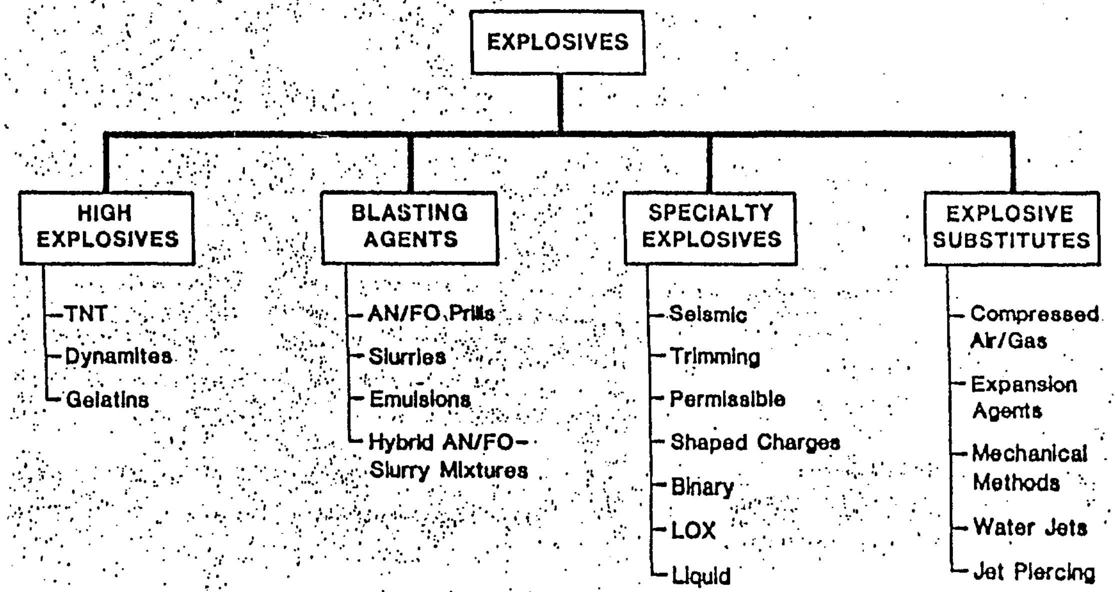
This is the fourth fatality reported in calendar year 2000 in the metal and nonme mining industries. As of this date in 1999, there were four fatalities reported in tl industries. This is the second fatality classified as Machinery in 2000. There we Machinery fatalities in the same period in 1999.

The information provided in this notice is based on preliminary data ONLY and does not represen determinations regarding the nature of the incident or conclusions regarding the cause of the fatal

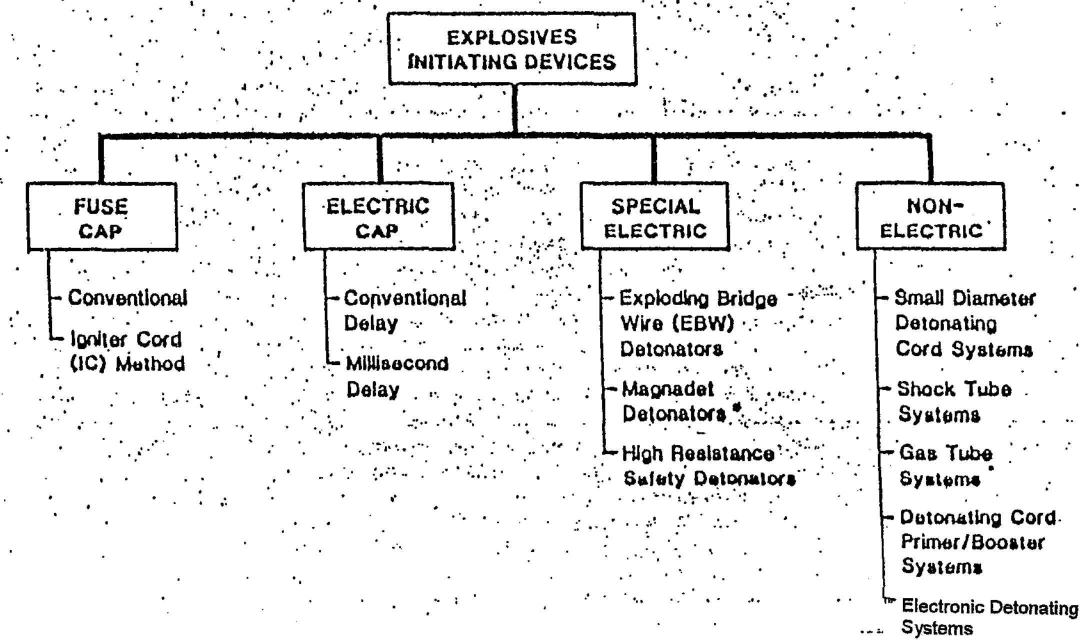
5. TOXIC FUMES

When blasting underground one must be concerned about toxic fumes generated by explosives. The quantity of fumes generated is related to several factors including the type of explosive, the weight of the explosive material detonated, its oxygen balance and the use of adequate primers. Toxic fumes are least when a properly formulated explosive material detonates close to its ideal velocity and generally increase when nonideal detonations occur. Explosive fumes principally consist of carbon monoxide and the oxides of nitrogen. After blasting it is important that affected areas are properly ventilated before workers are allowed to return. Serious incidents result when the blast damages the normal ventilation flow and miners return to work in toxic fumes. Good ventilation and gas sampling are the key to safe blasting operations in underground or other restricted areas. Current MSHA regulations require the mine operator to maintain good air quality in the working areas rather than restricting explosive types or quantity for use in an underground mine. Only the permissible explosives required for use in coal mines are tested for generated fumes. The values for other IME fume classes are calculated using computer codes. The IME fume classes, though not used by MSHA, are enforced by some States. In surface mines toxic blasting fumes such as nitrogen oxides are easily identified by the redish brown color and must be avoided till they are diluted with fresh air. Carbon monoxide is generally not a problem on surface mines unless it collects in some closed area or depression.

A Breakdown of Available Explosives



A Breakdown of Available Initiating Systems



Slurries

Slurry is a mixture of nitrates such as Ammonium nitrate and Sodium Nitrate, a fuel sensitizer, either explosive or nonexplosive, and varying amount of water. Water gel is essentially the same as a slurry and the two terms are frequently used interchangeably. An emulsion is somewhat different from a water gel or slurry in physical character but similar in many functional aspects.

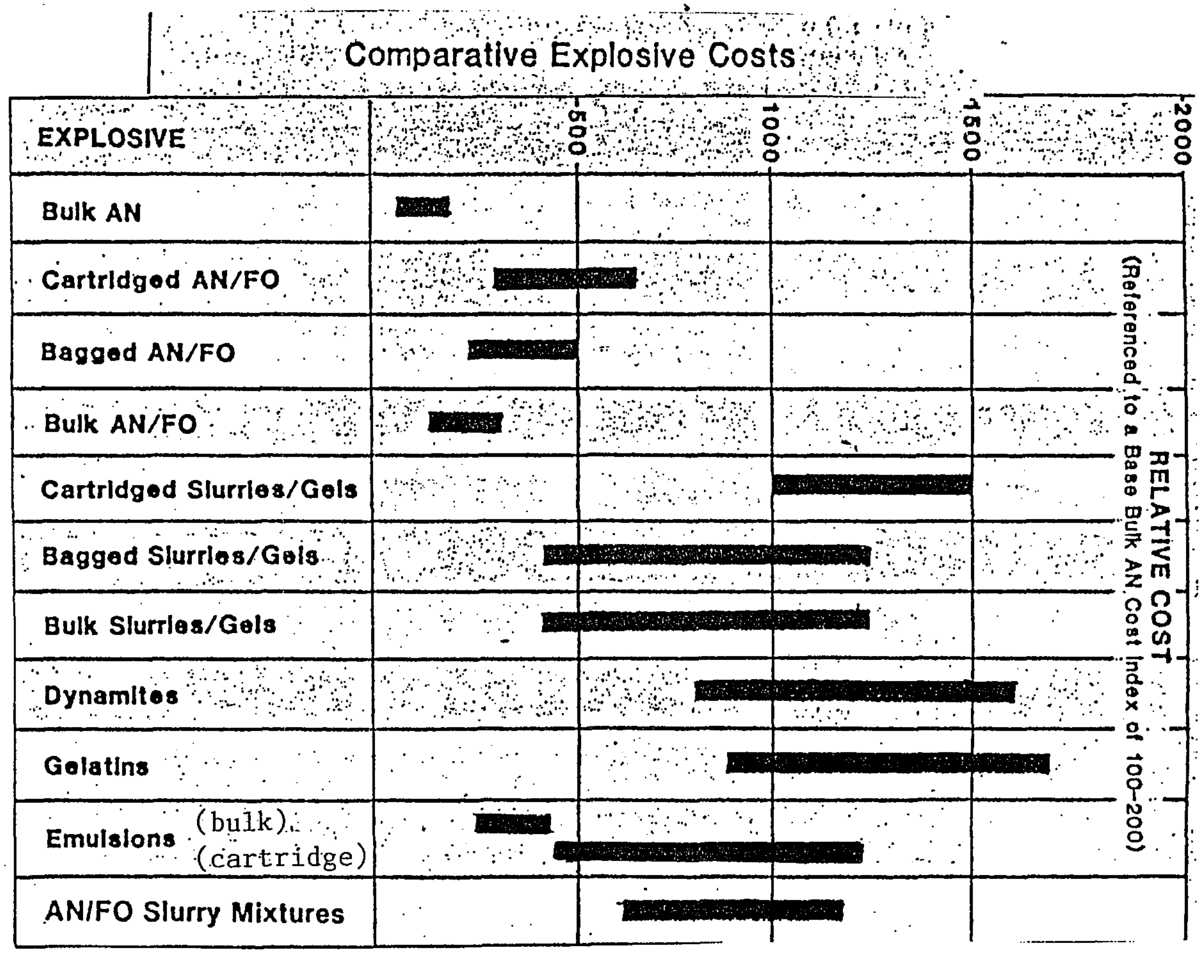
The principal differences are an emulsion's generally higher detonation velocity and tendency to adhere to blasthole. Although slurries and emulsions contain large mount of ammonium nitrate, slurries are made water resistant by the use of gums, waxes, and <u>cross-linking agents.</u> The variety of formulation is almost infinite. The most common fuel sensitizers are carbonaceous fuels, aluminum and amine nitrates. (MMAN). Slurries and Emulsions can be classified as either explosives or blasting agent. The consistency may be anywhere from liquid to a cohesive gel. Cartridged slurries for small diameter (less than 2"O) blastholes are normally made cap sensitive so they can be substituted for dynamite.

The sensitivity and performance of some grades of slurries are adversely affected by low temperatures. Non cap sensitive slurries must be primed with cap sensitive explosive. Detonating cord downlines can have a harmful effect on the efficiency of blasting agent slurries depending on the size of the blasthole and the strength of the cord.

Emulsion Explosive

Explosive material in the form of water-in-oil emulsions. The microscopically fine droplets of super saturated oxidizer salt solution are surrounded by a continuous fuel phase, and stabilized against liquid separation by an emulsifying agents. The oxidant and fuel ratio is approximately 10:1, particle size is approximately one micron, and detonation velocity is 16,000 to 20,000 ft./sec. Unlike other explosives, emulsions do not use chemical sensitizers. Instead, ultra fine air bubbles or artificial bubbles from glass, resin, plastic or some other material. Since each microsphere is coated with oily exterior, the water resistance is excellent and high detonation velocity providing high brisance or shock energy, a notable factor when blasting hard rock. Also, fuel grad Al can be added to vary the explosive strength.

The major disadvantage is, coagulation of nitrate solution in to large droplet when low temperatures, long distance transportation and prolonged storage periods. Particularity in small diameter cap sensitive charges. Bulk products are largely exempt from these problems and are usually mixed on site.


Comparative Explosive Costs
EXPLOSIVE
500
1000
1500
2000
Bulk AN
Cartridged AN/FO
Bagged AN/FO
Bulk AN/FO
Cartridged Slurries/Gels
Bagged Slurries/Gels
Bulk Slurries/Gels
Dynamites
Gelatins
Emulsions (bulk)
(cartridge)
AN/FO Slurry Mixtures
RELATIVE COST
(Referenced to a Base Bulk AN Cost Index of 100-200)

CAC TITLE 8. G.I.S.O. Section 5238

Definition and Classifications of Exposives.

"Explosives." Any substance or combination of substances that is commonly used for the purpose of detonation or rapid combustion which upon exposure to any external force or condition is capable of relatively instantaneous release of gas and heat.

(A) "Explosives, Class A." Possessing detonating or otherwise maximum hazard such as, but not limited to, dynamite, nitroglycerin, picric acid, lead azide, fulminate of mercury, black powder, RDX and PETN, more than 1000 blasting caps and detonating primers. This would include Class 7 Military Explosives.

(B) "Explosives, Class B" means that in general these explosives function by rapid combustion rather than detonation, and include such explosives devices as flash powers and propellent explosives which include some smokeless powders. This would include Class 2 Military Explosives.

(C) "Explosives, Class C" means and includes certain types of manufactured articles which contain Class A or Class B explosives, or both, as components but in restricted quantities.

"Explosives–Actuated Power Devices." Any tool or special mechanical device which is actuated by explosives, but not to include propellant actuated power devices. Examples of explosive actuated devices are jet perforators, shaped charges and similar devices.

"Fireworks." Any combination of oxidizing and combustible substances intended for display or signal purposes by either combustion or explosion and shall include such articles as fusees and railroad torpedoes, (also see "pyrotechnics.")

"Forbidden or not Acceptable Explosives." Explosives which are forbidden or not acceptable for transportation by common, contract or private carriers by rail freight, rail express, highway or water in accordance with the regulations of the U.S. Department of Transportation.

NOTE: Certain chemicals and certain fuel materials may have explosive characteristics but are not within the coverage of 18 U.S.C., Chapter 40 and are not specifically classified as explosives by the U.S. Department of Transportation. Authoritative information should be obtained for such materials and action commensurate with their hazards, location, isolation and safeguards, should be taken.

EXPLOSIVES UNITED NATIONS CLASSIFICATION.

Under the new system, all explosives materials will become U.N. Class 1 Explosives. Class 1 is further separated into six Divisions. The following is a listing of the Divisions along with the current class of materials that are contained in each:

Division 1.1 - explosives that have a mass explosion hazard.

(Class A Explosives - dynamites, cap-sensitive emulsions and water-gels, cast boosters, Class A detonators.)

Division 1.2 - explosives that have a projection hazard, but not a mass explosion hazard.

(Class A Explosives - primarily military ordnance.)

Division 1.3 - explosives that have a fire hazard and (1) a minor blast hazard or (2) a minor projection hazard, or both, but not a mass explosion hazard.

(Class B Explosives - propellant explosives.)

Division 1.4 - explosive devices that present a minor explosion hazard and contain 25 grams or less of detonating material.

(Class C Explosives - safety fuse, Class C detonators.)

Division 1.5 - very insensitive explosives which have a mass explosion hazard but are so insensitive that there is little probability of initiation.

(Blasting Agents - AN/FO, non cap-sensitive emulsions and water-gels, packaged AN/FO products.)

Division 1.6 - extremely insensitive articles which do not have a mass explosion hazard.

(There currently are no commercial explosive products that fit this classification.)

§ 173.52 Classification codes and compatibility groups of explosives.

(a) The classification code for an explosive, which is assigned by the Associate Administrator for Hazardous Materials Safety in accordance with this subpart, consists of the division number followed by the compatibility group letter. Compatibility group letters are used to specify the controls for the transportation, and storage related thereto, of explosives and to prevent an increase in hazard that might result if certain types of explosives were stored or transported together. Transportation compatibility requirements for carriers are prescribed in §§174.81, 175.78. 176.83 and 177.848 of this subchapter for transportation by rail, air, vessel, and public highway, respectively, and storage incidental thereto.

(b) Compatibility groups and classification codes for the various types of explosives are set forth in the following tables. Table 1 sets forth compatibility groups and classification codes for substances and articles described in the first column of Table 1. Table 2 shows the number of classification codes that are possible within each explosive division. Altogether, there are 35 possible classification codes for explosives.

TABLE 1—CLASSIFICATION CODES

Description of substances or article to be classified	Compatibility group	Classification code
Primary explosive substance	A	1.1A
Article containing a primary explosive substance and not containing two or more effective protective features.	B	1.1B 1.2B 1.4B
Propellant explosive substance or other deflagrating explosive substance or article containing such explosive substance.	C	1.1C 1.2C 1.3C 1.4C
Secondary detonating explosive substance or black powder or article containing a secondary detonating explosive substance, in each case without means of initiation and without a propelling charge, or article containing a primary explosive substance and containing two or more effective protective features.	D	1.1D 1.2D 1.4D 1.5D
Article containing a secondary detonating explosive substance, without means of initiation, with a propelling charge (other than one containing flammable liquid or hypergolic liquid).	E	1.1E 1.2E 1.4E
Article containing a secondary detonating explosive substance with its means of initiation, with a propelling charge (other than one containing flammable liquid or hypergolic liquid) or without a propelling charge.	F	1.1F 1.2F 1.3F 1.4F
Pyrotechnic substance or article containing a pyrotechnic substance, or article containing both an explosive substance and an illuminating, incendiary, tear-producing or smoke-producing substance (other than a water-activated article or one containing white phosphorus, phosphide or flammable liquid or gel or hypergolic liquid).	G	1.1G 1.2G 1.3G 1.4G
Article containing both an explosive substance and white phosphorus	H	1.2H 1.3H
Article containing both an explosive substance and flammable liquid or gel	J	1.1J 1.2J 1.3J
Article containing both an explosive substance and a toxic chemical agent	K	1.2K 1.3K
Explosive substance or article containing an explosive substance and presenting a special risk (e.g., due to water-activation or presence of hybergolic liquids, phosphides or pyrophoric substances) needing isolation of each type.	L	1.1L 1.2L 1.3L
Articles containing only extremely insensitive detonating substances.	N	1.6N
Substance or article so packed or designed that any hazardous effects arising from accidental functioning are limited to the extent that they do not significantly hinder or prohibit fire fighting or other emergency response efforts in the immediate vicinity of the package.	S	1.4S

TABLE 2—SCHEME OF CLASSIFICATION OF EXPLOSIVES, COMBINATION OF HAZARD DIVISION WITH COMPATIBILITY GROUP

	Compatibility group													
Hazard division	A	B	C	D	E	F	G	H	J	K	L	N	S	A–S
1.1	1.1A	1.1B	1.1C	1.1D	1.1E	1.1F	1.1G	....	1.1J	....	1.1L	....	....	9
1.2	....	1.2B	1.2C	1.2D	1.2E	1.2F	1.2G	1.2H	1.2J	1.2K	1.2L	....	....	10
1.3	....	....	1.3C	....	....	1.3F	1.3G	1.3H	1.3J	1.3K	1.3L	....	....	7
1.4	....	1.4B	1.4C	1.4D	1.4E	1.4F	1.4G	....	....	....	....	....	1.4S	7
1.5	....	....	....	1.5D	....	....	....	....	....	....	....	....	....	1
1.6	....	....	....	....	....	....	....	....	....	....	....	1.6N	....	1
1.6	1	3	4	4	3	4	4	2	3	2	3	1	1	35

§ 173.53 Provisions for using old classifications of explosives.

Where the classification system in effect prior to January 1, 1991, is referenced in State or local laws, ordinances or regulations not pertaining to the transportation of hazardous materials, the following table may be used to compare old and new hazard class names:

Current classification	Class name prior to Jan. 1, 1991
Division 1.1	Class A explosives.
Division 1.2	Class A or Class B explosives.
Division 1 3	Class B explosive.
Division 1.4	Class C explosives.
Division 1.5	Blasting agents.
Division 1.6	No applicable hazard class.

HAZARDS IN USE OF EXPLOSIVES

A. Transportation Hazards

1. The vehicle used to transport explosives should be in good operating condition. If the vehicle were to get a flat tire or lose its brakes it would lead to a serious hazard for everyone. The cargo space in which the explosives are stored should be of non-sparking material. If the vehicle got into an accident with damage to the cargo area, you would want to minimize any sparks that could set off the explosives.

2. Detonators and explosives should be kept apart by at least four inches of hardwood, or transported separately. If a detonator were to accidently fire this would prevent it from setting off any explosives.

3. Explosives should be transported at times when the fewest number of people will be endangered. During shift change or lunch breaks are usually good times to bring explosives into the pit.

4. Explosives should not be stacked higher than the sideboards of the vehicle. If the vehicle were to hit a bump some boxes could fall off the side.

5. No smoking is permitted on or near the vehicle. Hot ashes or flames pose a danger when mixed with powder.

6. If ANFO or any other powder is spilled it should be immediately cleaned up.

7. Do not attempt to catch a ride around the pit on a vehicle carrying explosives. The driver should not be distracted from performing his work.

8. Vehicles should be driven carefully and excessive speeds should be avoided. Do not drive over unbridged power cables.

9. Vehicles loaded with explosives should not drive into any maintenance area where sparks from welding or stray electric currents could set off explosives.

B. Magazine Hazards

1. Magazines must be built in dry, isolated areas and must be well ventilated, bullet-proof, locked, and have non-sparking material on the inside wall. It must be marked with a sign located in such a place that if a bullet were to be fired into it the bullet would not pass into the stored powder. Depending upon the size of the pit, the magazine may be located within the pit in a safe area, or outside the pit a safe distance from other buildings and equipment.

2. Flammable materials such as fuel or oil should not be stored near a magazine.

3. Smoking in and around a magazine is prohibited.

4. Detonators and explosives should not be stored together in the same magazine. Separate magazines for them should be at least 25 feet apart.

5. The magazine must be kept clean of trash, empty boxes and paper at all times. They are both a fire hazard and a cause of slips and falls/

6. No electric wiring or open lights should be taken into a magazine.

7. Surplus or loose explosives should not be left in unsecured areas such as beside idle equipment, or by the outside walls of the magazine.

C. Detonator Hazards

1. Do not let leg wires and detonators come into contact with electrical equipment, wires or rails. These may carry enough of a current to set off the charge.

2. Caps can deteriorate and become more sensitive because of age. Caps may also become useless from such damage as being kinked, exposed to extreme heat, or contaminated with water. They should be properly disposed but only by experienced powdermen.

D. Blasting Hazards

1. A misfire is a loaded hole in the highwall that fails to fire. The procedure following firing a round is that the blaster or supervisor will inspect the rock pile for misfires. No one else is permitted to enter the area until the all-clear signal is given.

    a. If the blaster finds a misfire he will attempt to re-wire and detonate it or flush it out of the drill hole with water and dispose of it.

    b. In the event the misfire is completely covered by rock, the blaster may not see it. This results in a very dangerous situation. Do not attempt to move it yourself. If you discover a misfire in the rock, work should stop immediately, the area should be cleared and guarded, and the supervisor should be contacted.

    c. Toxic fumes and dust may be found after detonation. You can avoid these fumes as well as the dust by remaining out of the blast area until the open air dilutes the gases and the dust settles down.

        i. Carbon monoxide can be detected by observing one of the first symptoms of such poisoning - headache pain.

        ii. Explosives containing nitroglycerine or other nitro compounds may burn rather than detonate. One gas resulting from this is nitrogen dioxide which is extremely dangerous to your lungs in small amounts. It has a burned powder odor.

        iii. Wet ANFO will generate nitrous oxide fumes.

Blasting Hazards - cont.

2. Overshooting results from either an excessive use of explosives, an improperly sized drill hole, or holes that are not properly placed according to the delay pattern. Undershooting is just the opposite. Overshooting weakens the rock remaining in the highwall making it susceptible to falls due to gravity, water, and wind. Undershooting results in an uneven highwall and creates haulage problems by having to move larger sized rocks.

3. Fly rock consists of rock blown from the shot area by the explosive force. This rock can be lethal because of its weight and velocity of travel. Fly rock is also caused by a blowout. When a blast hole is not drilled deep enough into the rock, the explosive force blows the rock out into the drift or work area.

4. Electrical hazards are present if the mine uses electric blasting caps.

   a. Natural sources like static electricity or lighting storms.

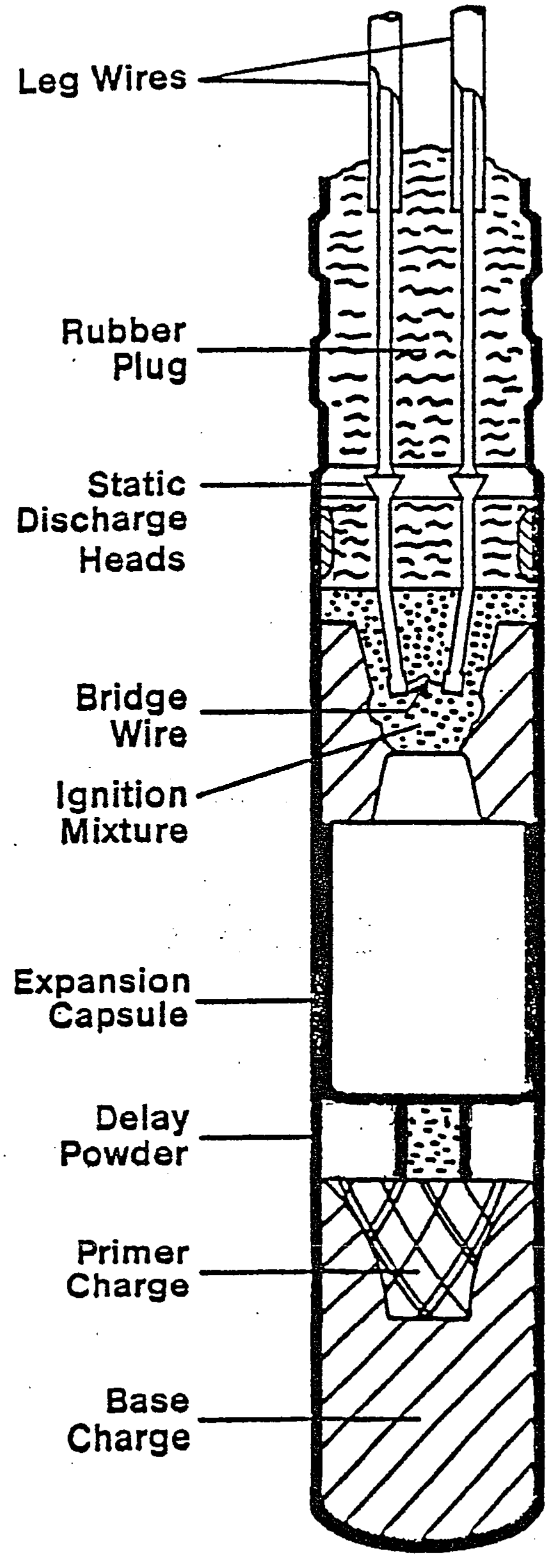
   b. Man-made sources like stray electricity and radio transmitters.

   c. Only special galvanometers should be used to test continuity. Regular galvanometers may set off the charge. If you find a cap in the rock pile do not attempt to test the leg wires - only experienced powdermen are equipped to do such work.

   d. Any power equipment with leaking current presents a hazard.

   e. Static charge built up from pneumatic loading equipment.

5. Never drill into a bootleg - it could contain a charge of powder that might detonate when struck by the drill steel. Prior checks of the hole may have accidentally not detected the powder, so do not take any shortcuts.



Millisecond Delay Electric Blasting Cap

Rule of Thumb in Blast Design

Bore hole Diameter.

Bore hole diameter in inches should be approximately one tenth of the bench height in feet.

$$D = \frac{H}{10}$$

D = Bore hole diameter (inches).
H = Bench height (feet)

- Small diameter hole can reduce the number of joints between holes, reduce oversize fragmentation and better distribution of explosives.

- More holes required, lower bench height, lower production

Burden.

Distance from a bore hole to the nearest free face at the time of blasting.

Burden dimension in feet should be approximately 2.5 times of the bore hole diameter in inches.

$$B = 2.50$$

B = Burden dimension (feet)
D = Bore hole diameter (inches)

Also, optimum burden dimension maybe adjusted in combination of bore hole diameter, bore hole depth, spacing, delay pattern, explosives used, rock mass characteristics degree of fragmentation, muck pile shape sought, vibration and air blast control.

Spacing.

Spacing is a distance between adjacent holes and a function of the burden.

S = 1 to 2 X B S = Spacing (feet)
B = Burden (feet)

Spacings that are smaller than burden tend to cause early stemming ejection and premature splitting between holes, result in fly rocks, noise and air blast. Conversely, too large spacing may cause inadequate fragmentation and uneven floor.

Bench Height.

The choice of bench height is usually decided by safety factor (stability of formation and equipment used.)

However, minimum bench height shall be;

Hm = 2 X B Hm = Minimum Bench Height (feet)
B = Burden (feet)

H = 10 D D = Bore hole diameter (inches)
H = Bench Height in general

Subdrilling.

Subdrilling is the drilling below the designed floor level.

Bad fragmentation problem occur at the bottom of the hole where highest energy is required to move the rock. Too much subdrilling causes excessive ground vibration and waste of money. Too little subdrilling causes high bottom, causing secondary blasting and excessive equipment wear.

Natural rock formation greatly effect the amount of subdrilling, but rule of thumb is 30% of the burden distance.

$$J = 0.3 \times B$$

J = Subdrilling (feet)
B = Burden (feet)

When blasting number of rows, the amount of subdrilling on the back row should be increased due to the area for rock movement getting tight and cause fly rock problem.

Stemming.

Inert substances loaded on the top of explosive charge is stemming and gives confinement of explosion gases. The size distribution and amount of material is a major factor controlling fly rock and air blast.

It maybe calculated as;

$$T = 0.7 \text{ to } 1.3 \times B$$

T = Stemming (feet)
B = Burden (feet)

Relatively fine and closely sized stone that will tightly pack will be good. It is common practice to use drill cuttings, however if cap rock exists or holes are wet to the collar, crushed stone material.

Delay Timing.

Minimum delay between adjacent holes or corresponding decks in adjacent holes should be approximately 1 ms./ft of burden.

Average rate of blast progression along the free face should be less than the velocity of sound in air (1.100 ft.sec.)

$$\frac{\text{Distance}}{\text{Delay time}} < 1.100'$$

If you use 25 ms. delay, spacing shall be less than 1.100 X .025 < 27.5'

Minimum delay between rows should be greater than average delay between holes.

Correctly applied delay reduces cut-offs in explosive column due to hole shifting, noise, ground vibration.

The minimum separation between delay period should be 8 ms. or more to confirm Federal requirement.

Vibration and Air blast.

Ground vibration and Air blast become a serious problem to any blasting operation close to populated area.

Peak particle velocity (PPV) is the best descriptor for predicting the probability of structural damage due to ground vibrations.

Air blast hazard is usually compensated automatically, if explosive loading is followed to eliminate ground vibration damage.

Bureau of mine study in 1971 (Bulletin #656) and 1980 (RI #8507) found that;

PPV 2"/sec. - Will probability of little damage to a structure.

PPV 1"/sec. - Maximum allowable by the Surface Mining Control and Reclamation Act (P.L. 95-87)

PPV 0.4"/sec. - Should prevent minimize complaint from adjacent property owners.

PPV 0.15"/sec - Conservative scale distance of 70 [redacted] relieve operator from instrumentation of shots.

Many regulatory agencies have adapted the criterion of maximum particle velocity between 2 inches to as low as 0.23 inches without considering frequencies.

Bureau of Mine study shows that damage potential for low-frequency blast (<40 Hz) are considerably higher than high frequency (>40 Hz) blast.

Scale Distance.

Scale distance is derived as a combination of distance and explosive charge weight influencing the generation of seismic or air blast energy. Where vibration is not a serious problem, law often permit the blaster to use the scaled distance equation rather than seismograph.

$SD. = D/W^{\frac{1}{2}}$

SD = Scale distance

D = Distance from the blast (feet)

W = Maximum charge weight (lbs.)

$W = (D/SD)^2$

$D = SD \times (W)^{\frac{1}{2}}$

Bureau of Mine Bulletin #565 says that a scaled distance of 50 or greater will protect against vibration greater than 2 inch/sec.

• Therefore, at a distance of 500 ft., 100 lbs. of explosive could be fired.

$W = (D/SD)^2 = (500/50)^2 = 10^2 = 100$ lbs.

• At distance of 1000 ft.

$W = (1000/50)^2 = 20^2 = 400$ lbs.

400 lbs. of explosive could be fired.

The Office of Surface Mine (OSM) regulation specified a SD = 60 or greater to protect against PPV 1 inch/sec.

• Therefore, at distance of 600 ft.

100 lbs. of explosive could be fired.

$W = (D/SD)^2 = (600/60)^2 = 100$ lbs.

• At distance of 1200 ft.

$W = (1200/60)^2 = 20^2 = 400$ lbs.

400 lbs of explosive could be fired.

SHOT CALCULATIONS

Scaled Distance

$$D_S = \frac{D}{\sqrt{W}} \quad \text{or} \quad W = \left(\frac{D}{D_S}\right)^2$$

$$D = D_S \times \sqrt{W}$$

D = Distance in Feet to Nearest Structure
W = Maximum Weight in Lbs Per Delay
D_S = Scaled Distance

Weight VS. Scaled Distance

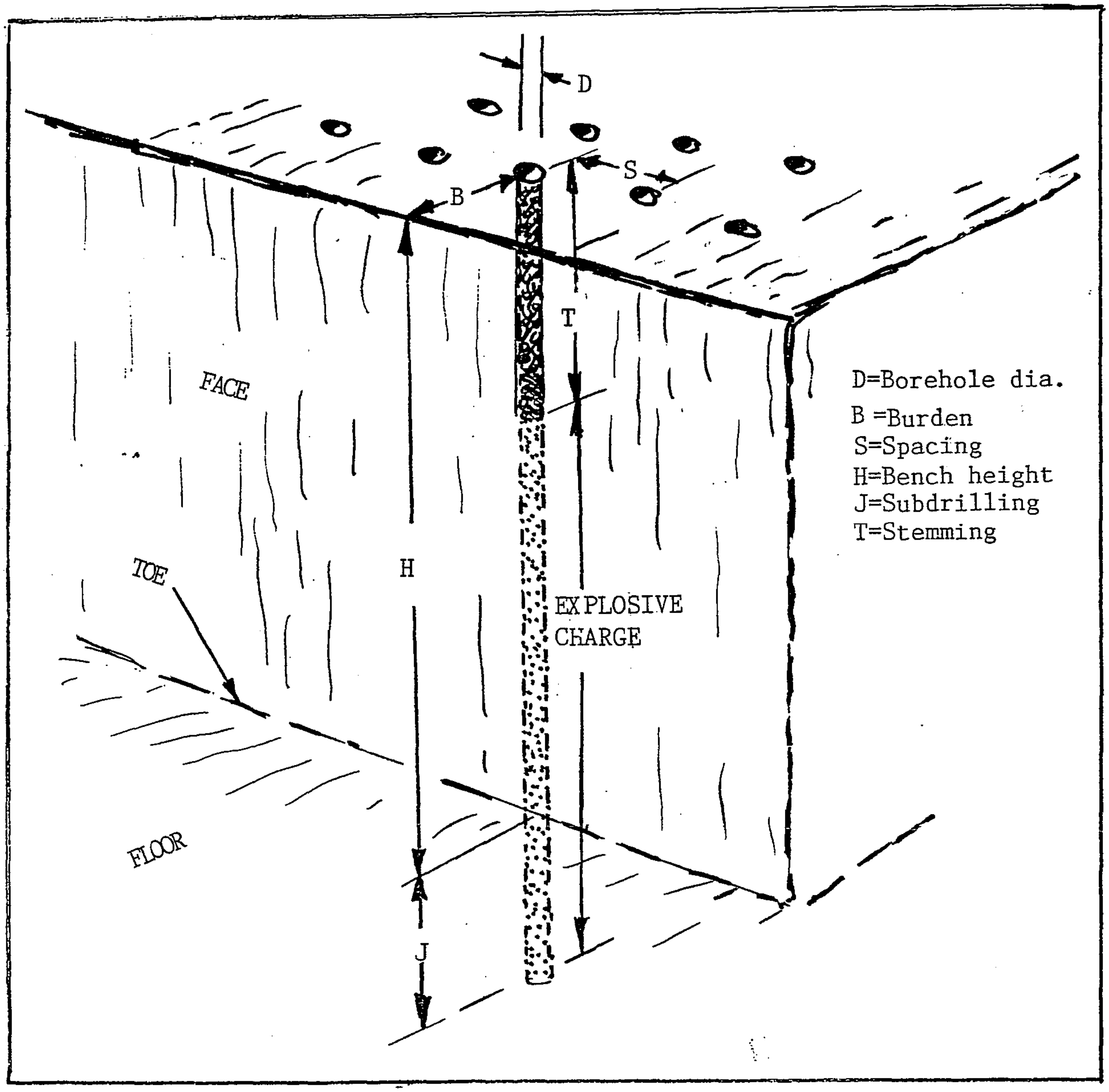
	$D_S=50$	$D_S=55$	$D_S=60$
D(Ft.)	W(Lbs.)	W(Lbs.)	W(Lbs.)
300	36	30	25
400	64	53	44
500	100	83	69
600	144	119	100
700	196	162	136
800	256	212	178
900	324	268	225
1000	400	331	278
1200	576	476	400
1400	784	648	544
1600	1024	846	711
1800	1296	1070	900
2000	1600	1322	1111
2500	2500	2066	1736
3000	3600	2975	2500
3500	4900	4050	3402

Average Weight of Various Solid Materials

Name	Tons Per Cubic Yard
Andesite	**2.42**
Basalt (N.Y.)	**2.48**
Coal - Anthracite (Pa.)	**1.35**
Coal - Bituminous (W. Va., Ky.)	**1.15**
Coal (Wy.)	**1.08**
Diabase (fine grain, Mich.)	**2.48**
Dolomite (Tenn.)	**2.40**
Gabbro (altered, N.Y.)	**2.46**
Granite	**2.21**
Greenstone (Mich.)	**2.79**
Gypsum (Ind.)	**1.94**
Hematite	**4.12**
Limestone	**2.27**

Name	Tons Per Cubic Yard
Limestone (fossiliferous)	**1.94**
Limestone (Ohio)	**2.27**
Quartzite (taconite, Minn.)	**2.32**
Rock Salt (La.)	**2.11**
Sandstone (W.Va.)	**2.11**
Sandstone (Utah)	**1.84**
Sandstone (Ala.)	**2.32**
Shale (Utah)	**2.38**
Shale (W.Va.)	**2.03**
Syenite	**2.30**
Talc	**2.23**

SCHEMATIC OF TYPICAL DRILL PATTERN



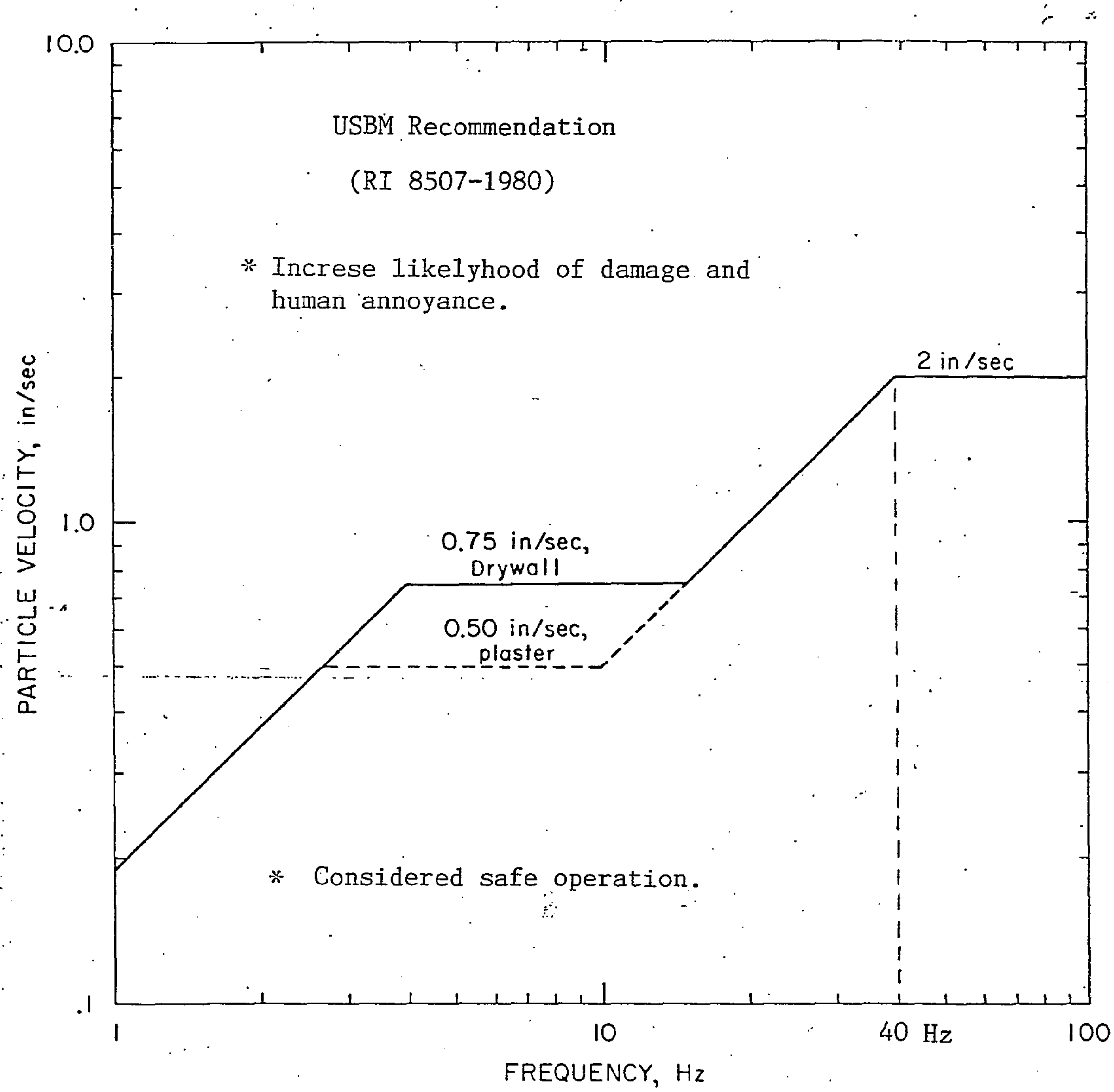
CONVERSION TABLE DECIBELS AND P.S.I.

Db	P.S.I.	Db	P.S.I.	Db	P.S.I.
100	.00032	116	.002	132	.0126
101	.00035	117	.0022	133	.0141
102	.0004	118	.0025	134	.0159
103	.00045	119	.0028	135	.0178
104	.0005	120	.0032	136	.0199
105	.00056	121	.0035	137	.0224
106	.00063	122	.00396	138	.0251
107	.00071	123	.0045	139	.0282
108	.00079	124	.0050	140	.0316
109	.00089	125	.0056	141	.0355
110	.001	126	.0063	142	.0398
111	.0011	127	.0071	143	.0447
112	.0013	128	.0079	144	.0501
113	.0014	129	.0089	145	.0562
114	.0016	130	.0100	146	.0631
115	.0018	131	.0112	147	.0708

$$\text{Trace Velocity} = \frac{\text{Spacing' x 1,000}}{\text{MS Time Between Holes}} = \text{F.P.S.}$$

NOTE: Speed of sound = 1,100 F.P.S.

****



Safe levels of blasting vibration for houses using a combination of velocity and displacement.

Quiz on Blasting Safety

The following is a pre-test that has been given at several blasting seminars sponsored by the Kentucky Department of Mines and Minerals to gauge the attendees' familiarity with safety facts and procedures. The answers to the questions, and a brief explanation of each answer is given at the end of the quiz. However, local regulations, or specific company policies may mean that there are more correct answers than those given here. In any case, these questions may constitute a basis for discussion during a safety meeting.

QUESTIONS

1. Which of the following is the leading cause of blasting fatalities and injuries?

A. Misfires
B. Excessive Flyrock
C. Premature Blasts
D. Inadequate Blast Area Security.
E. Disposing of Explosives

2. The majority of blasting accidents are impossible to prevent because they are result of some freak occurrence.

A. True
B. False

3. Each year a number of children are injured when they accidentally detonate blasting caps. In the majority of these cases, the kids got the blasting caps

A. by buying them from a powder company.
B. by finding them on abandoned construction projects or mine sites.
C. by finding them in the trash or in landfills.
D. by breaking into magazines and stealing them.
E. by finding them around their home or in barns or vehicles near where they live.

4. Which of the following initiation systems is the most hazardous?

A. Electric blasting caps
B. Non-electric caps
C. Cap and Fuse
D. Detonating Cord
E. Each one is dangerous depending upon who is using it and where.

5. As long as a blaster sounds a warning, and clears the area prior to blasting, he has met his responsibility for securing the blast area.

A. True
B. False

6. It is entirely possible for a person to learn everything necessary to become a competent blaster in the classroom and by reading manufacturers publications.

A. True
B. False

7. Accident statistics indicate that the type of blasting operations which are most dangerous to the blasting crew are those where they

A. load very deep and large diameter boreholes with thousands of pounds of blasting agents.
B. load small diameter holes with cartridge high explosives.
C. work on a surface coal mine.
D. are all former government employees.

8. No sane person ever risks his life when he is aware of the danger.

A. True
B. False

9. If a blaster is using electric caps and wants to check the continuity of his firing circuit but his blaster's galvanometer(ohmmeter) is broken and not available, he may use

A. an electrician's voltmeter
B. any type of ohmmeter
C. a light bulb and a flashlight battery
D. a sequential blasting machine
E. no other type of an instrument

10. Most fatalities and injuries that are a result of a misfire occur when the employees are

A. trying to determine the cause of the misfire.
B. trying to correct the reason for the misfire.
C. nearby when electricity or heat initiate a misfired charge.
D. excavating or digging into the broken rock.

11. Faulty or defective blasting equipment is a common cause of blasting accidents.

A. True
B. False

12. If the blaster has deteriorated explosives in his magazine, he should

A. use them in the next blast he loads.
B. dispose of them properly.
C. return them to the manufacturer.
D. turn them over to MSHA, OSHA or some other government agency.
E. discard them because they will not detonate.

13. If a thunderstorm approaches while a crew is loading a shot with non-electric initiators, the blaster

A. must cease operations and clear the area.
B. may continue to drill and load provided there are no electrical detonators on the site.
C. may continue to drill and load, but may not fire the blast until the storm passes by.
D. may continue to drill on the site, but not load any explosives in the holes.
E. may continue if all equipment is grounded.

14. If a blaster is working near a radio transmitter, the danger of a premature detonation exists if he is using

A. electric blasting caps
B. non-electric caps
C. safety fuse and caps.
D. any type of detonator.

15. If a detonator or blasting cap gets stuck in a cast primer, and the blaster cannot remove it easily by hand, he should:

A. use a pliers to pull it loose.
B. use a screwdriver or powder punch to pry it out.
C. return the primer to the magazine.

D. cut it out with a non-sparking knife or saw.
E. discard this primer down a borehole to be shot, if it will not readily separate.

ANSWERS:

1. D. Data collected by the U.S. Bureau of Mines from 1978 to 1989 showed that inadequate blast area security resulted in 51.9 % of the fatal and nonfatal blasting accidents.
   Other causes were flyrock, premature blasts, and misfires in descending order of occurrence.

2. B. Nearly all company and government safety officials will confirm that most accidents they investigate are caused by careless acts or omissions of people. Likewise a review of accident reports will indicate that most result from a breakdown in the normal safety precautions.

3. E. A review of this type of accident reports clearly indicate that children most often find the blasting caps which injure them in or near their home. Parents or other adults may bring excess detonators home from their job, or detonators remaining after a blasting project may be carelessly stored or discarded.

4. E. All initiation systems, and all explosives for that matter, are dangerous in the hands of persons not familiar with them or those persons who use a particular system inappropriately.

5. B. To adequately secure the blast area means that the blaster must do more than simply look to make sure no one is present and sound a warning. It includes giving clear instructions to everyone on the site as to when and where the blast will be detonated, posting signs and guards, or constructing barricades in order to control access into the site, and firing the blast at a safe location and under sufficient cover.

6. B. To become a proficient as a blaster requires field experience under the supervision of a competent blaster. There are so many variations in geology, equipment, explosive materials, that actual practice is necessary to learn. While classroom training is beneficial, nearly all regulatory agencies recognize the importance of on the job training and require field experience in order to become a licensed or certified blaster.

7. B. Accident reports from mines and construction projects indicate that a blaster and his crew are most exposed to danger and injury when working on jobs with small diameter drills and loading boreholes with cartridge high explosives. The proximity of people and equipment to the primer and the sensitivity of the explosive materials create a more hazardous environment than one where thousands of pounds of blasting agents may be fired in very large and deep boreholes.

8. B. Too often people risk their lives both on the job and in their personal lives. A very simple example is the fact that many people will drive late at night when they are sleepy, even though they consciously know that such behavior is inherently dangerous. It seems to be human nature for a person to underestimate the negative safety consequences of their actions, usually by rationalizing that nothing bad will happen to them.

9. E. In addition to being specifically prohibited by laws and regulations, common sense should tell a blaster that nothing is ever used to test an electric detonator or detonator circuit, except an approved blasting galvanometer or ohmmeter. Both the Institute of Makers of Explosives, as well as the individual manufacturers of detonators publish clear and unequivocal warnings that only instruments that are specifically designed to test electric detonators or their circuits shall be used.

10. D. Due to the fact that a misfire is a charge that does not detonate, it is obvious that the occurrence itself does not directly injure or kill. It is in the aftermath of a misfire, that a serious hazard exists to the blaster and those around him as they try to resolve the problem. Often a misfire results in unexploded charges being mixed with the blasted rock; in such a situation, any one excavating this material could cause the charges to fire due to impact or friction.

11. B. As in question # 2 above, seldom does the investigation of a blasting accident indicate that the equipment was faulty or defective. Nearly always, the direct cause of a blasting accident is careless act or omission.

12. B. Deteriorated explosives should never be used, but disposed of properly. Proper disposal must be done under the supervision of a knowledgeable and authorized person and in accord with applicable laws and company policies. The manufacturer of the explosives in question is the best source for information on disposal.

13. A. Regardless of what type of initiation system is being used, the blaster should cease operations and clear the area whenever an electrical storm approaches. Even non-electric detonators and tubing can be initiated by a direct lightning strike.

14. A. Radio frequency (RF) energy poses a danger to those blasters using electric detonators because it may induce sufficient electrical energy into the circuit of the detonator to cause it to fire. Non-electric detonators, caps and fuse, and detonating cord are immune to such RF energy and should be used in locations near significant radio transmitters. If in doubt regarding safe distances from transmitters, the best reference document available is the Institute of Makers of Explosives publication No. 20, "Safety Guide for the prevention of Radio Frequency Energy Radiation Hazards in the Use of Commercial Electric Detonators."

15. E. A blaster should never use any tool to force a detonator into or pry a detonator out of a primer cartridge. In this example, the creation of a primer (a high explosive cartridge containing a detonator) is a hazard which cannot be safely or legally stored or transported. One alternative is to detonate it either alone, or in a borehole with other explosives. This is a situation which company policy or local regulations may address, and these should be consulted. However, in no case should such a primer be returned or stored in the explosive magazine.

This quiz was contributed by Larry Schneider