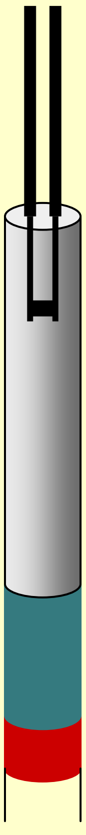
Explosives



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

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

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

DISCLAIMER

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

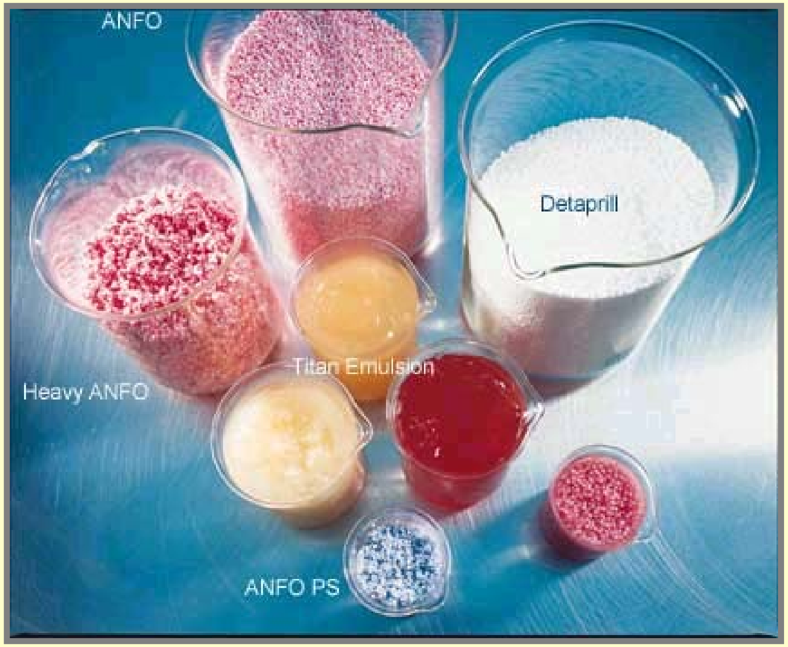
Explosives

This module presents information pertaining to the classification and properties of explosive products used in surface coal mines and quarries.

Chemistry of Explosives

Explosives are chemical mixtures or compounds that, when subjected to heat, impact, or shock, are capable of undergoing a rapid decomposition that releases heat and gases, which, in turn, expand to form high pressures.

Detonation occurs when the rate of chemical decomposition is greater than the speed of sound; **deflagration** occurs when the reaction rate is slower than the speed of sound. “High explosives” detonate, whereas “low explosives” deflagrate or burn.



A high-explosives detonation provides both shock, which fractures (or breaks) the rock, and force (in the form of gas products), which heaves and displaces the fractured rock.

All explosives are mixtures that include **carbon, nitrogen**, **hydrogen**, and **oxygen,** along with other additives that affect or provide special properties (for example, density, viscosity, and water resistance).

Chemistry of Explosives

Detonation forms two types of gas products:

- Harmless gases, which include:
  - H_2O (as water vapor),
  - CO_2 (carbon dioxide),
  - N_2 (nitrogen),
  - NH_4 (ammonia), and
  - CH_4 (methane), and
- Gases that are potentially toxic, which include:
  - CO (carbon monoxide),
  - NO (nitric oxide),
  - N_2O (nitrous oxide), and
  - NO_2 (nitrogen dioxide).

Nitrogen oxides (NO_x) form dark brown fumes after a coal-mine cast blast.

Oxygen Balance

When the explosive mixture in a blasthole contains the correct amount of oxygen, and the explosives' physical properties as designed have not been altered by anything[1] that would degrade their quality, no toxic fumes are produced, and the energy released by the reaction is a maximum. This condition is referred to as oxygen-balanced. With an oxygen-balanced mixture, there is sufficient oxygen to oxidize all of the ingredients necessary to produce H_2O, CO_2, and N_2.

Oxygen imbalance can occur for a variety of reasons. (See the "Blasthole Loading" module.)

[1]Many factors can cause an explosive to degrade. For example, water in a borehole can corrupt an explosive like ammonium-nitrate fuel oil, which isn't water-resistant (ammonium nitrate is hydroscopic and will dissolve in water). In a deep borehole, pressure in the bottom can alter an explosive's density by causing micro-balloons to be crushed. Shock waves from detonating boreholes can dead-press (squeeze out tiny air bubbles from or collapse glass micro-balloons in) explosives in the holes that have not yet detonated.

Classification of Explosives

There are many ways to classify explosives.

One is to think of mixtures as part fuel or sensitizer and part oxidizer (or something that provides oxygen to the fuel). Examples of fuels and sensitizers, as well as oxygen source, are:

Fuels (or sensitizers) +	Oxidizers (oxygen source) =	**EXPLOSIVES**
*fuel oil (**FO**)*	*ammonium nitrate (**AN**)*	
carbon	*calcium nitrate*	
aluminum	*sodium nitrate*	
trinitrotoluene (TNT)		
cyclonite (RDX)		
smokeless powder		
aerating agents		
micro-balloons		

Classification of Explosives

The Bureau of Alcohol Tobacco, Firearms and Explosives (ATF) defines explosives as:

Low explosive (LE) = an explosive material that can be caused to deflagrate (burn) when unconfined;

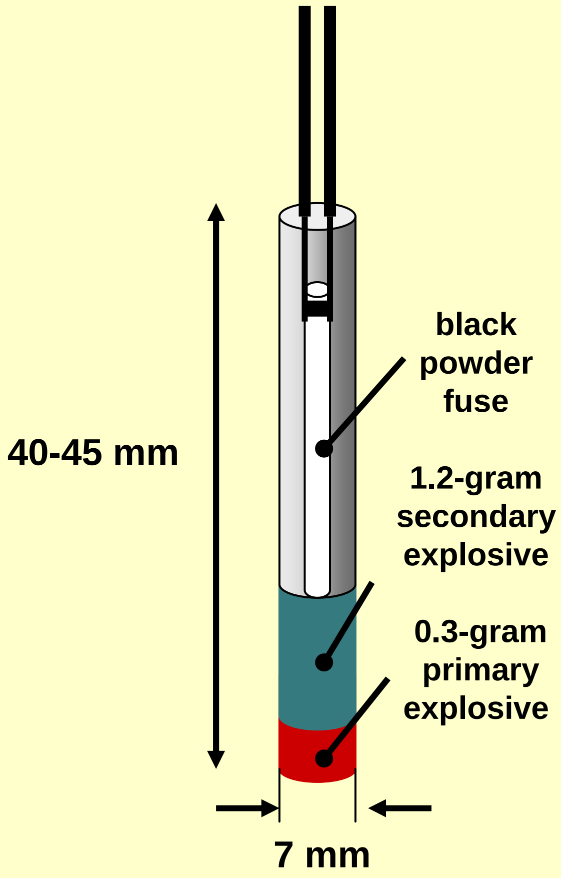
High explosive (HE) = an explosive material that can be caused to detonate with a No. 8 blasting cap when unconfined; and

Blasting agent (BA) = a mixture consisting of a fuel and oxidizer, intended for blasting but otherwise not an explosive (cannot be detonated with a No. 8 blasting cap).

The makeup of a standard-test No. 8 cap, of the sort used as a detonator in the blasting industry, is shown to the right.

HE's that can be detonated directly with a No. 8 cap are called **cap-sensitive.**

BA's that cannot be detonated directly with a No. 8 cap are called **cap-insensitive** or **non-cap-sensitive.**



Classification of Explosives

The following three categories comprise generic types of explosives (specific types of explosives are addressed later on in the module):

LE’s

- black powder

HE’s

- dynamites
  - straight dynamite
  - ammonia dynamite
- gelatin dynamite
  - straight gelatin
  - ammonia gelatin
- semi-gelatins
- binary
- water gels, slurries
  - emulsions

BA’s

- water gels, slurries
  - emulsions
- ANFO
  - blends

It is worth noting that water gels, slurries, and emulsion products can be formulated to produce either (1) cap-sensitive HE’s—by adding sufficient amounts of HE sensitizers—or (2) BA’s—by omitting such sensitizers. Note as well that BA blends are usually mixtures, in varying percentages, of ammonium-nitrate fuel oil (ANFO) and emulsion.

Explosive Properties

Density

Density is normally expressed in terms of specific gravity or mass divided by volume, as follows:

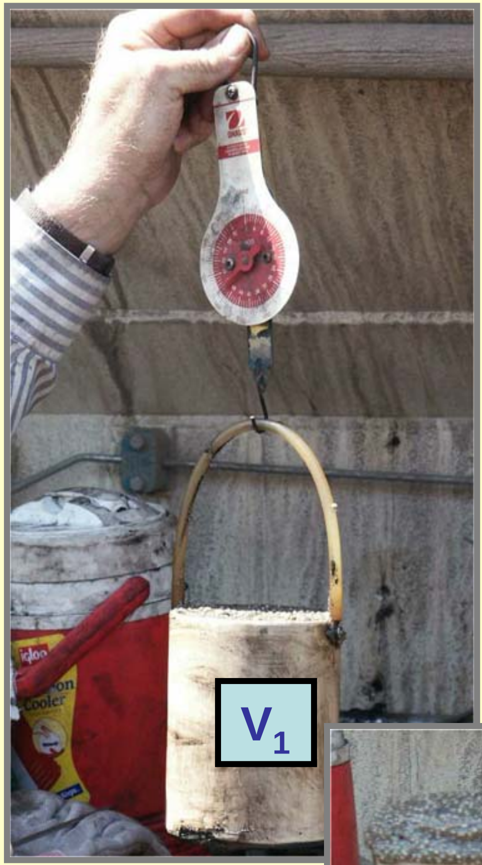
grams/cubic centimeter = g/cm^3 = g/cc.

(***Note that the convention here is typically to use the metric [g/cc] rather than the imperial [g/cm³] measurement system. This is because the density of water in metric units is 1.0 g/cc; by using the metric unit, a comparison can be made between the explosive and water.***)

Explosives with bulk densities less than 1.0 g/cc may not readily sink in water, whereas explosives with densities greater than 1.0 g/cc should sink in water, including standing blasthole water.

Two types of density are important:

- package and
- free-running product.



Gassing agents added to explosives (V_1, to the left) can selectively decrease the density of emulsion-blend products (V_2, below) in the blasthole. (Note, as well, that the volume of V_2 is also increased as compared with that of V_1.)

The Two Types of Density

Package Density

The density of an explosive as packaged in a cartridge or tube at the mixing plant (1) is set by formulation and does not change (unless the package is broken during loading) and (2) must be greater than the density of that same explosive in the blasthole. If air gaps are introduced around the explosive when loading its cartridge or tube into a blasthole, its charges may decouple.

Bulk Density

The bulk density of a free-running explosive poured from a bag or bulk-loading truck is improved with good coupling along the side of the blasthole. The density is somewhat modified by the particle sizes and fall height of the mix.

Explosive Properties

Loading Density

An explosive's loading density (LD) is defined as the weight of explosive per unit length of borehole at a specified hole diameter. Expressed in pounds per foot, LD is computed as:

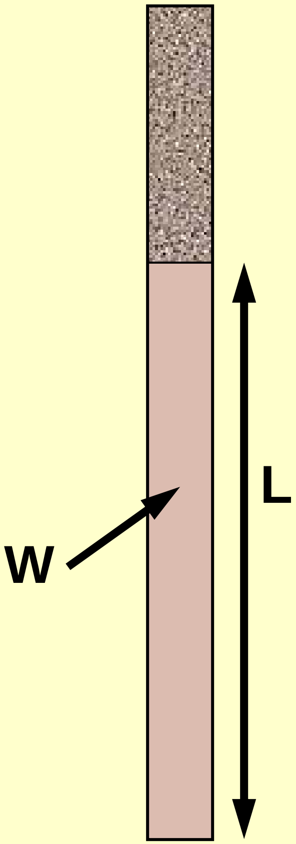
$$LD\ (lbs/ft) = 0.3405\ \rho\ D^2$$

where D is the borehole drilled diameter in inches and ρ is the explosive density in g/cm^3.

The LD value may also be computed by dividing the total explosives charge weight loaded into a hole (W) by the length of the loaded hole (L), thus:

$$LD = W/L.$$

Knowing the LD of an explosive is typically of greatest use in the field.



Explosive Properties

Water Resistance

The ability of an explosive product to withstand exposure to water without either losing power or becoming desensitized is termed that explosive's water resistance. Water resistance is generally expressed as the number of hours a product may remain submerged under water and still reliably detonate. Manufacturers rate resistance to water as good to poor. Many commercial explosives are mixed with the prospect of their potential exposure to water in mind.

The detonation energy of ANFO mixtures that have been exposed to water in blastholes is far less than that of such mixtures placed in dry holes.

On the other hand, blasting agents manufactured with water as part of their ingredients may have excellent water-resistance properties. The same is true for explosives packaged to protect the ingredients from water intrusion.

Water-resistance ratings are available from manufacturers of explosives and should be used as a guideline when selecting explosives for rock blasting.

Explosive Properties

Fume Class

Fume class is a measure of the amount of toxic gases, primarily CO and NO_x, produced by the detonation of an explosive. Most commercial blasting products are oxygen-balanced to minimize the fumes and optimize the energy they release. Fumes are an important consideration in confined spaces—for example, tunnels and shafts—and should be considered under surface-blasting scenarios where fumes could travel offsite and impact nearby residential areas.

Any factor that may change the chemistry of an explosive during detonation (such as the balance of fuel to oxidizer) has the chance to upset the oxygen balance designed for the mixture. Such factors can include:

- Insufficient charge diameter,
- Inadequate priming,
- Improper delay timing,
- Water deterioration, and
- Plastic borehole liners or paper wrappers.

MSHA, the Institute of Makers of Explosives (IME), and the former U.S. Bureau of Mines have developed fume-classification or rating tests, in laboratory settings, for explosives used in underground metal and coal mines. Many of these tests do not necessarily scale to surface-blasting situations. In surface mines, blasting may produce a variety of fumes that include NO_x (which is orange in color) and CO (which is colorless).

If gases are of concern at any surface-blasting operation, samples may be taken and tested by trained specialists.

Explosive Properties

Flammability

As a Measure of an Explosive's Fire or Blast Hazard When Subjected to Flame

The ease with which an explosive or BA can be ignited and/or detonated when subjected to heat either confined or unconfined is termed that explosive's flammability. For purposes of classification, the Department of Transportation, explosives manufacturers, and the military have developed many ignition, burn-rate, and detonation tests.

Some commercial explosives with high fuel content may readily ignite and burn. In confined spaces, burning may lead to detonation. ANFO and water-based explosives such as water gels and emulsions are more difficult to ignite in the open. ***A blaster who has any explosives-flammability concerns MUST discuss them with the explosives' manufacturer(s).***

As a Measure of an Explosive's Capacity to Create Fire from an Open Flame Carried by Its Detonation

Years ago, permissible explosives were developed for use in underground coal and other gassy mines. Permissibles were formulated with salt to lower their flame temperatures and prevent gas explosions. Today, in surface coal mines, detonating cord and other devices that carry an open flame are still used to fragment thick coal. As a consequence, because coal is a fuel source, detonation flames may lead to localized combustion within detonated coal seams. However, because such resultant fires are typically small, this situation presents merely as a nuisance in that time must be taken to extinguish the fires if they occur.

Detonating cord used to fragment coal.

Explosive Properties

Temperature

Extremely low temperatures can affect the performance of water-based explosives, the ingredients of which can solidify and aggregate, thereby reducing the particle surface area available for reaction. A lower performance results. At higher temperatures, the crystal structure of AN can be affected, and a reduction of particle size can occur with crystal changes (breakdown). Often, this change in crystal structure is progressive within a mix and over time. Temperature fluctuations under this scenario can result in high density states at which the explosive may no longer detonate.

Other temperature effects may include the burning (or deflagration) of mixtures that have been subjected to the intense heating of pyrite oxidation, which is often associated with sulfur-bearing metals and coal mines.

Shelf Life

The chemical stability and performance of explosives change with age. The extent of instabilities and the rate of aging will depend upon the formulation and storage conditions of the explosive; accordingly, modern explosive materials contain inhibitors and/or stabilizers that lengthen their shelf lives. For example, certain military-type explosives are extremely stable over a wide range of conditions for long periods amounting to virtually unlimited shelf life. It is always best practice to store explosive materials so that common brands, sizes, grades, and "Date-Plant-Shift" codes remain together and stocks can be rotated so that the oldest materials are used first.

Explosive Properties

Sensitivity

The term sensitivity, as it pertains to explosives, has two meanings that may seem, on first consideration, to contradict each other. The contradiction is resolved, however, as follows:

The first meaning of the sensitivity as it relates to explosives refers to various **safety aspects** and describes the ease with which an explosive may be detonated or its sensitivity to accidental detonation from shock, impact, friction, electrostatic discharge, and heat. Numerous laboratory and field tests (such as the pendulum test, which uses the device to the right) have been developed over the years to test shock, heat, and friction sensitivity.

The second meaning has to do with **sensitiveness or an explosive's ability to propagate**. In this sense, the amount of energy (usually from heat and shock) required to reliably produce a detonation determines an explosive's sensitivity. Sensitivity under this definition can be measured in a number of ways. Two tests that are most applicable to commercial explosives are:

- *Cap sensitivity*, which measures the ability of an explosive to be detonated with a standard No. 8 cap; and
- *Gap sensitivity*, which measures the ability of a detonation to propagate across a space—termed a "separation gap"—between two charges that have been placed adjacent to each other.

Explosive Properties

Strength

The measure of an explosive's energy, on both a weight and a volume basis and calculated or measured using field tests, is termed that explosive's strength. Strength is related to density and detonating velocity, as well as the heat and gas volume the explosive liberates upon detonation; this value can be calculated, or it can be measured using a variety of tests (for example, the ballistic-mortar, underwater-bubble, the cratering, and the strain-pulse tests). These tests can identify relative measures of blasting performance for trial explosive mixes. However, they do not provide accurate measures of the total energy available in any given borehole to do the work intended (i.e., to fragment and displace rock).

The total energy released from the detonation of explosives includes both useful energy (the energy that actually fragments and displaces rock) and wasted energy (heat, light, ground vibrations, and airblast). The efficiency of an explosive to do useful work varies from application to application and is dependent on formulation, borehole diameter, environmental loading conditions, and confinement.

Based on tests or computer calculations, explosives manufacturers rate explosives energy in either kilocalories (Kcal) per unit weight or Kcal per unit volume, as follows:

- Absolute Weight Strength = the heat of reaction available in each gram (weight) of explosive, whereas
- Absolute Bulk Strength = the heat of reaction available in each cubic centimeter (volume) of explosive.

Data are also available—for heat of reaction for explosives relative to ANFO—as the standard of comparison:

- Relative Weight Strength = the heat of reaction per unit weight of an explosive as compared with ANFO; or
- Relative Bulk Strength = the heat of reaction per unit volume of an explosive as compared with ANFO.

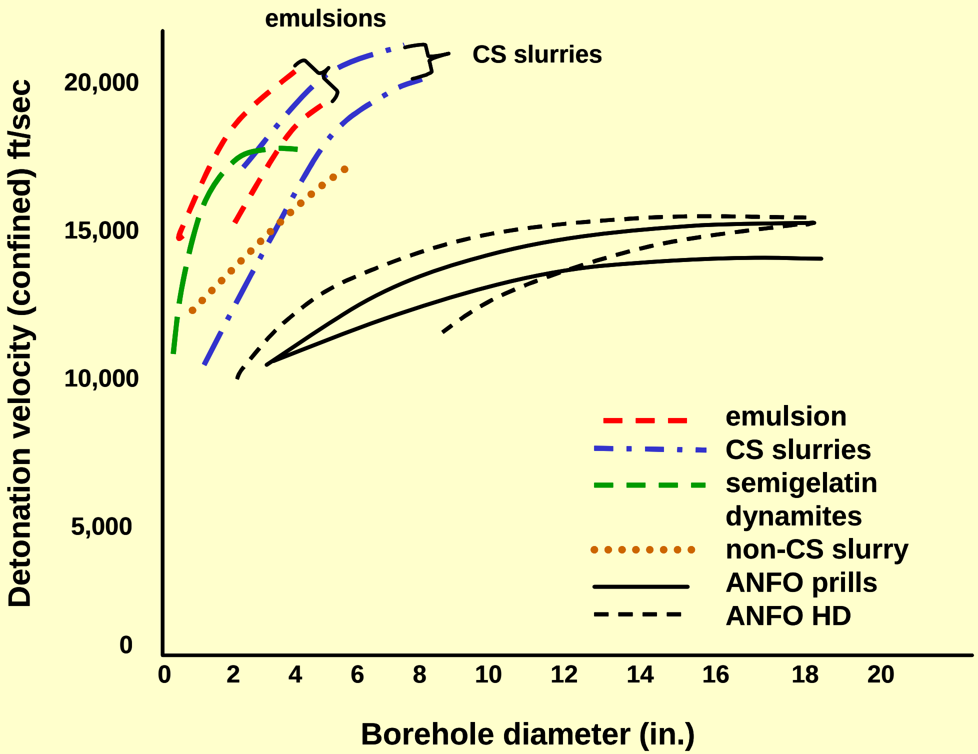
Explosive Properties

Detonation Velocity

The detonation velocity of an explosive is the speed at which the detonation, once it achieves a steady state, travels through the explosive.

This value is a function of formulation, density, borehole diameter, primer size, and confinement.

The figure to the right shows generalized relationships between borehole diameter and detonation velocity for various explosive types.



CS = cap-sensitive.

Explosive Properties

Detonation Pressure

The pressure associated with a detonation moving through an explosive, measured in kilobars (kbar) or pounds/in^2 (psi), is defined as detonation pressure. Detonation pressure is a function of detonation velocity and density, computed using computer models. Approximating formulas, like the one that follows, are available:

$$P = 0.2322 \times \dot{\rho} \times V^2 \times 10^{-6},$$

where V = detonation velocity (ft/sec),
$\dot{\rho}$ = specific gravity (g/cm^3),
P = detonation pressure (kbars), and
1 kbar = 14,504 psi.

Detonation pressure is chiefly responsible for the intense rock shearing near a borehole; such pressure for commercial explosives ranges from 25 to over 240 kbar (that is, from 0.36×10^6 to 3.48×10^6 psi).

Borehole Pressure

The pressure exerted on borehole walls by the expanding gases of a detonation, after the chemical reaction has been completed, is defined as borehole pressure. Borehole pressure is a function of confinement and the quantity and temperature of the gases of detonation; it is generally considered to play the dominant role in displacing rock during blasting.

Borehole pressures of the gas products expanding in the borehole roughly equal 45 to 50 percent of the detonation pressure.

Review Question

1. Compute the detonation pressure for a product with a detonation velocity of 16,000 ft/s and a density of 1.2 g/cm^3.

Answer

1. An approximation formula for detonation pressure tells us that:

   $P = 0.2322 \times V^2 \times \dot{\rho} \times 10^{-6}$

   Calculating using the values in our question,

   $0.2322 \times (16{,}000)^2 \times (1.2\ g/cm^3) \times 10^{-6} = 71.33$ kbars.

   Converting to psi, 71.33 kbar x 14,504 psi/kbar = 1.03×10^6 psi.

Explosives and BA's

- LE's
  - black powder
- **HE's**
  - **dynamites**
    - **straight dynamite**
    - **ammonia dynamite**
  - **gelatin dynamite**
    - **straight gelatin**
    - **ammonia gelatin**
  - **semi-gelatins**
  - binary
  - water gels, slurries
  - emulsions
- BA's
  - water gels, slurries
  - emulsions
  - ANFO
  - blends

Nitroglycerine-Based Explosives

Nitroglycerin-Based HE's

Nitroglycerin-based (NG-based) HE's are classified according to grade or weight strength in terms of the relative percentage of NG and other fuels they contain. NG-based explosives are very sensitive.

The oldest of the HE's to be classified as NG-based is dynamite, which was developed by Alfred Nobel over 130 years ago. Over the years, NG has been replaced with increasing quantities of AN.

Today, there are three basic types of dynamite: granular, gelatin, and semi-gelatin. Densities among these types can range from 0.8 to 1.7 g/cm^3, detonation velocity from 6,500 to 25,000 ft/s, and detonation pressure from 9.7 to 190 kbar.

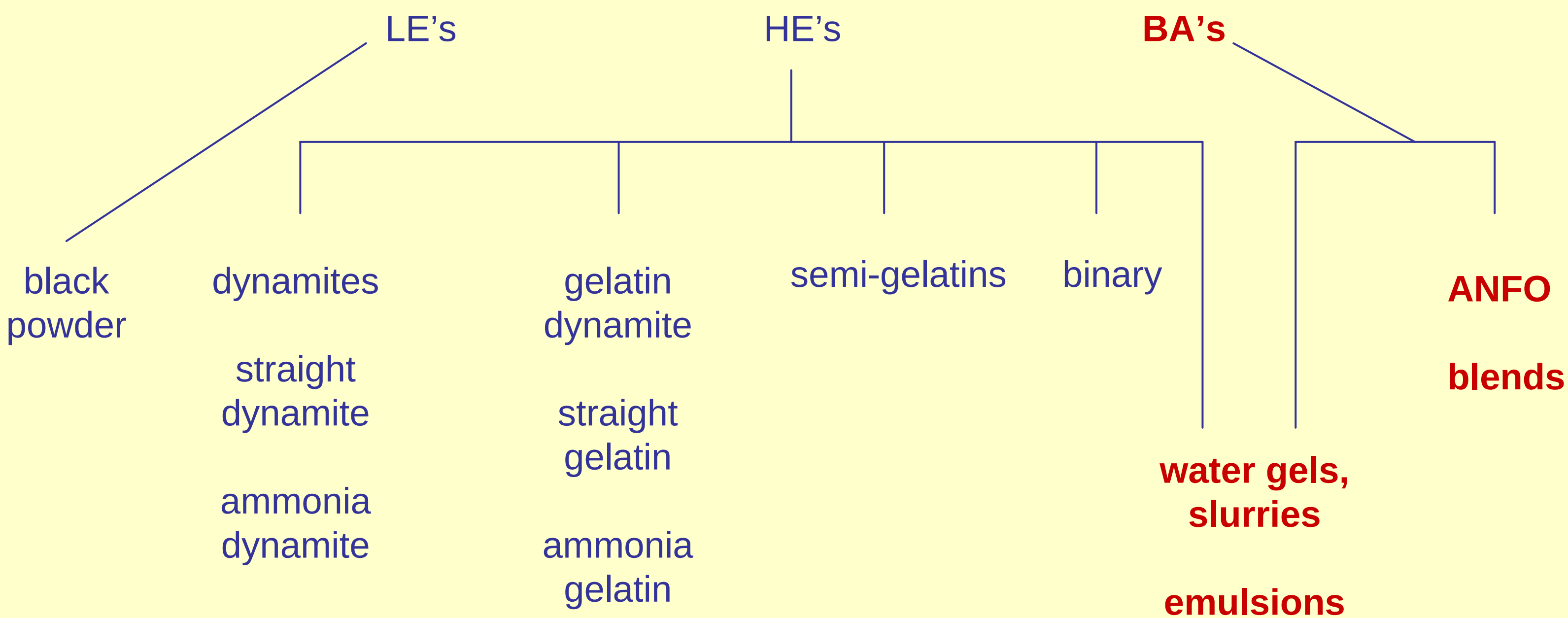
	Weight strength (as a percentage of NG)
Straight[1] dynamite	50
Extra[2] (or ammonia) dynamite (AN replaces NG)	40-60
Straight gelatin	20-90
Extra (or ammonia) gelatin	40-60
Semi-gelatin, extra only (this is a combination of ammonium dynamite and ammonium gelatin)	Variable.[3]

[1]"Straight" in this context refers to the absence of ammonia formulation.

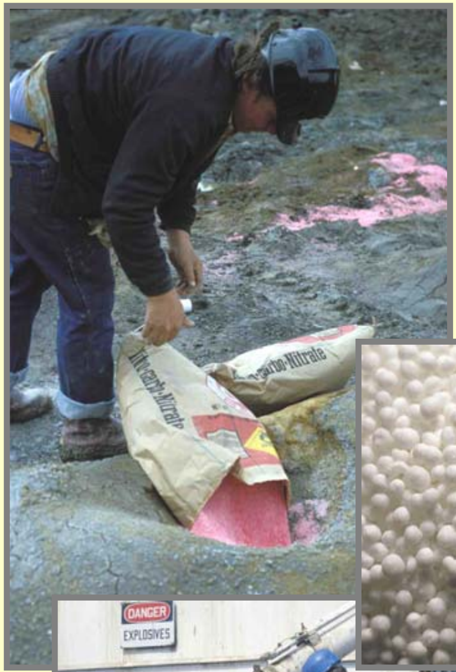
[2]"Extra" means that AN is added to replace part or all of the NG.

[3]The weight strength of semi-gelatins typically varies. Semi-gelatins cost less than gelatins, provide moderately high detonation pressures, and demonstrate adequate water-resistance for most conditions.

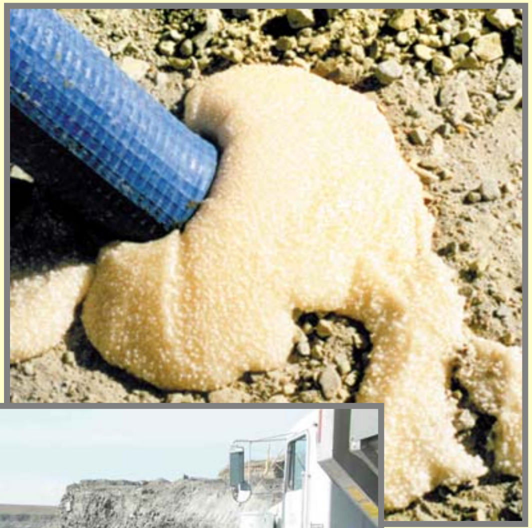
Explosives and BA’s



Classification of BA’s



BA’s are either dry (free-running; shown to the left) or wet (pourable; shown to the right). Wet BA’s are formulated with water to achieve a density greater than 1.0.



Dry BA’s are not formulated with water.

Dry BA’s: ANFO

ANFO

Dry BA’s comprise blasting-grade prilled AN (as the oxidizer), of grain sizes between 1 to 2 millimeters in diameter and porosity between 8 to 12 percent, onto which is absorbed diesel oil (FO, as a fuel).

Ammonium Nitrate + Fuel Oil = ANFO

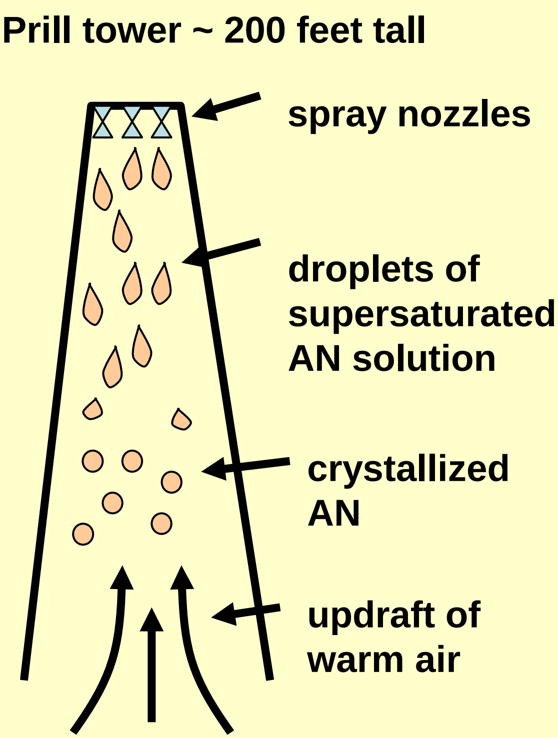
To achieve oxygen balance, the ANFO mixture should have:

- 94-percent AN and
- 6-percent FO.

Today, ANFO is the most widely used explosive in the blasting industry, because it is relatively inexpensive and safe to handle.

1–2 mm

Dry BA's: ANFO



Explosive-grade prills are made in a prill tower in which a hot, supersaturate AN liquid (4-percent water)—along with other additives to achieve porosity—is dropped from spray nozzles at a height of 100 to 200 feet against an updraft of warm air.

Droplets of the AN solution crystallize as they fall; the longer the droplets are suspended, the larger the prill diameters.

The crystallized AN particles are then completely dried and coated with surfactants and clay to minimize porosity and protect the surface from absorbing water in preparation for fuel absorption.

Porosities range from 8 to 12 percent, whereas solid-grain densities range from 1.3 to 1.5 g/cm^3. Particle sizes range from 0.83 to 2.3 mm in diameter. By comparison to explosive-grade prills, agricultural-grade prills are less porous (3- to 5-percent porosity) and far more dense.

Dry BA's: ANFO

Packaged in 50-pound bags or bulk-loaded from trucks, ANFO has properties as follows:

- Bulk density = 0.82 - 0.95 g/cm^3,
- Detonation velocity = 10,000 - 14,500 ft/sec, and
- Detonation pressure = 20 - 25 kbar.

Advantages of ANFO

The advantages of ANFO are:

- It is cheap;
- It is easy and safe to manufacture; and
- It may be handled in bulk to save costs.

Disadvantages of ANFO

The disadvantages of ANFO are:

- It is not water-resistant;
- Its density is low;
- It is non-ideal reacting; and
- It is not cap-sensitive and must be initiated with a primer.

Wet BA's: Water Gels and Slurries

A water-gel or slurry explosive is a gelatinous aqueous solution that consists of an oxidizer, such as AN, and a fuel. Typically, the fuel will contain additional dispersed solid oxidizers, fuels, and sensitizers such as aluminum or other explosives. Wet-BA fuel may also contain micro-balloons (hollow bubbles of glass). The difference between a slurry and water gel is that water gel is made water-resistant by the addition of a cross-linking or chemical-bonding agent; a slurry, on the other hand, is water-resistant (formulated to be miscible in water) by nature.

Packaged in plastic tubes or bulk loaded from trucks, wet BA's exhibit properties as follows:

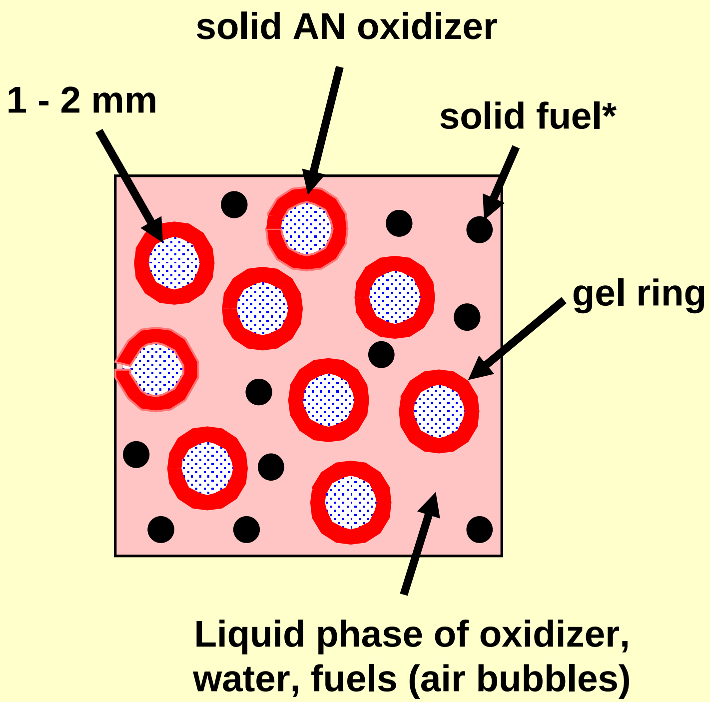
- Bulk density = 1.0 - 1.35 g/cm^3,
- Detonation velocity = 13,000 - 19,000 ft/sec, and
- Detonation pressure = 50 - 100 kbar.

Advantages of Water Gels

Water gels exceed slurry explosives in that (1) they are an excellent product for wet holes and (2) the density of a water gel can be controlled.

Disadvantages of Water Gels

Water gels are less effective than slurry explosives (1) at low ambient temperatures and (2) if the supersaturated solution of AN crystallizes, causing an imbalance of oxidizers and fuels in their two phases (that is, in their solid and liquid forms).



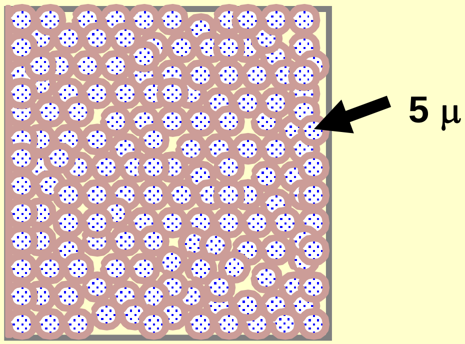
*An example of a cap-sensitive solid fuel is TNT; an example of non-cap-sensitive solid fuel is aluminum.

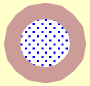
Wet BA's: Emulsions

Emulsions

Emulsions are "water-in-oil" mixes that were developed in the early 1960's to improve the performance of water gels. They amount to hot solutions of oxidizer salts (consisting of ammonium, AN, calcium, CN or sodium, SN, and nitrates) mixed with oil and an emulsifying agent. The oil phase usually consists of diesel fuel and/or mineral oil that include micro-balloons as sensitizers.

The oxidizer solution is broken up into small, micron-sized droplets, which form a discontinuous phase within the continuous oil phase.





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liquid oxidizer (AN) surrounded by liquid fuels and sensitizers

The small size of the liquid-nitrated salt particles provides a large surface areas-to-volume ratio that amounts to more fuel being placed in intimate contact with the oxidizer. This, in turn, allows for a very fast detonation rate and a powerful explosive.

Packaged in plastic tube or bulk-loaded from trucks, emulsions exhibit properties as follows:

- Bulk density = 1.15 - 1.45 g/cm^3,
- Detonation velocity = 14,500 - 18,500 ft/sec, and
- Detonation pressure = 100 - 120 kbar.

Emulsions

Advantages of Emulsions

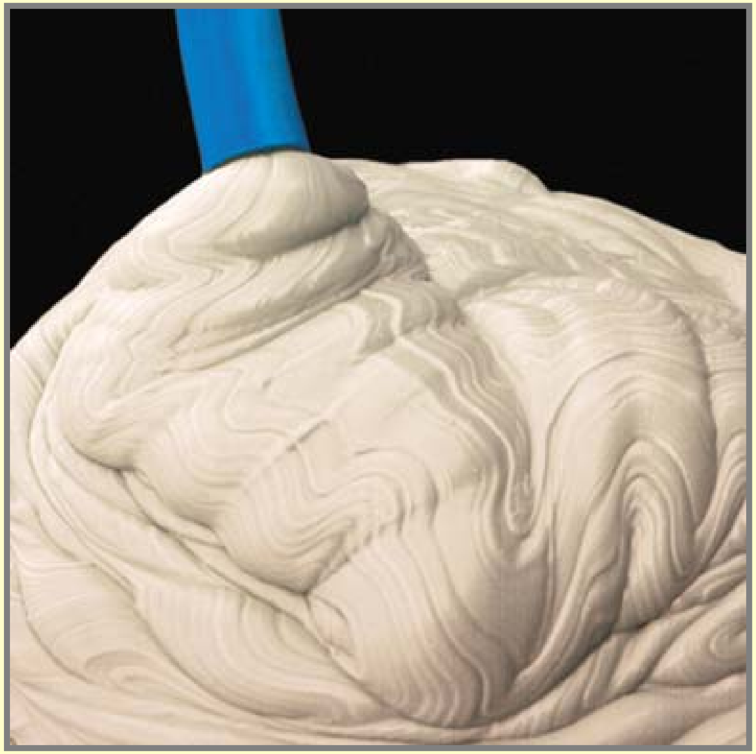
- Owing to their very small particle size, emulsion ingredients can achieve a very uniform mix.

- Emulsions are extremely water-resistant.

Disadvantages of Emulsions

- Over time (with long shelf life), salt crystals may grow and/or oil migrate in an emulsion, allowing the AN liquid-phase droplets to join and create larger droplet sizes whose bulk surface areas are smaller. Under such a scenario, less oxidizer would be in contact with the fuel and the sensitivity of the emulsion would decrease.

- Emulsions are expensive.



ANFO/Emulsion Blends

Blends (or heavy ANFO's) are mixtures of emulsions and ANFO that are typically non-cap-sensitive. As a rule, the ratio of emulsion (or other water-based explosive or oxidizer matrix) to ANFO in such blends ranges as follows:

Percentage		
Emulsion	ANFO	-
20	80	
40	60	***Water-resistance***
50	50	
60	40	
80	20	+

Packaged in plastic tube or bulk-loaded from trucks, ANFO/emulsion blends exhibit properties as follows:

- Bulk density = 1.15 - 1.30 g/cm^3,
- Detonation velocity = 16,700 - 17,500 ft/sec, and
- Detonation pressure = 40 - 55 kbar.

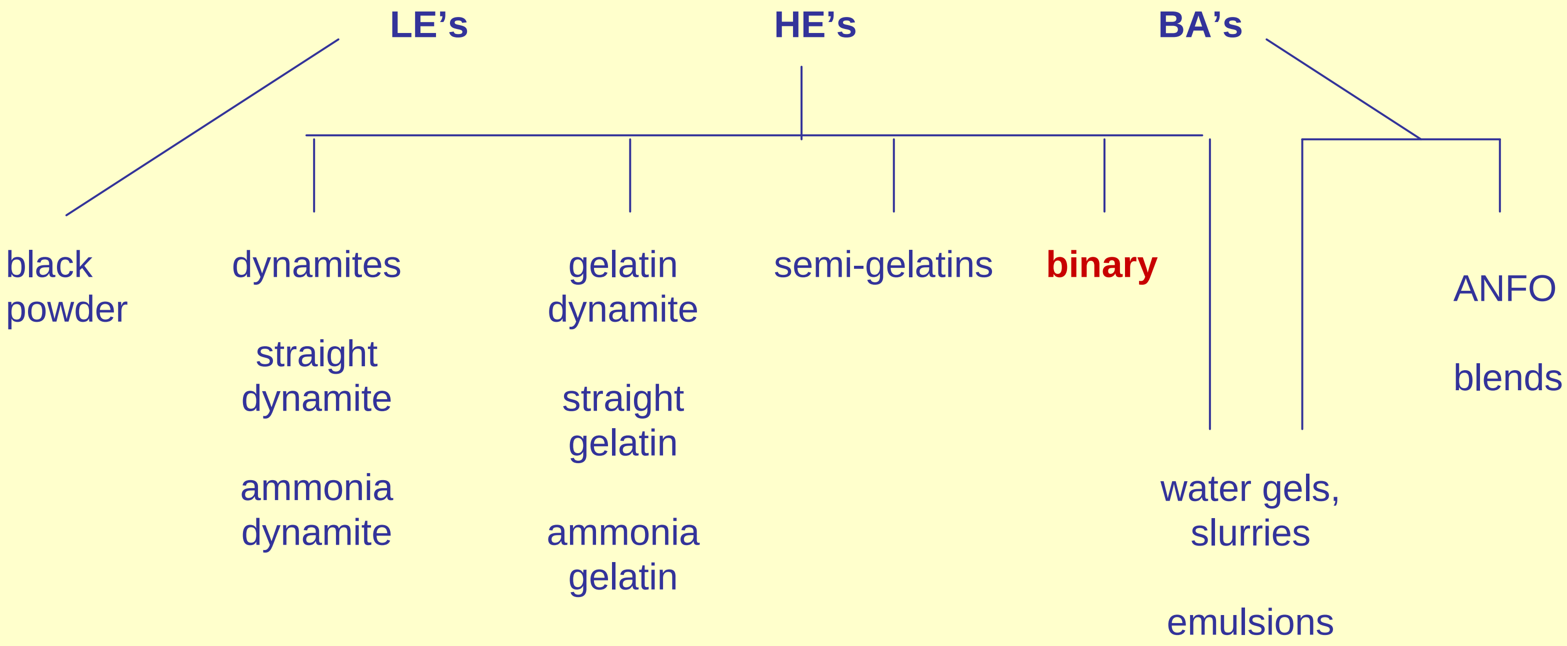
Advantages of Blends

Blends increase the density of ANFO, which increases the energy in the borehole; they also provide water-resistance to ANFO.

Disadvantages of Blends

Over time, fuels may migrate and salt crystals may grow increasingly insensitive.

Explosives and BA’s



Binary Explosives

Binary, or two-component, explosives are formed by mixing or combining two commercially manufactured prepackaged chemical ingredients that consist of oxidizers and flammable liquid or solid fuel. Individually, neither component is classified as an explosive; however, when mixed together, the two components constitute a cap-sensitive HE.

The unmixed ingredients for binary explosives are not subject to transportation requirements applicable to Class-1 hazardous materials, and they do not need to be stored in an approved, licensed (or permitted) explosive-storage magazine. Binary explosives are popular with blasters who only occasionally need to use explosives and who do not have available magazine storage.

A typical binary explosive is considered to be equivalent in strength to a 60-percent dynamite containing no NG. Binary explosive are normally packaged in rigid plastic cartridges and plastic-coated aluminum foil pouches.

Boosters and Primers

Boosters and primers are used to initiate non-cap-sensitive BA’s that are not HE’s. However, it is critical to remember that **these agents are themselves HE’s:** ***boosters and primers*** **can be initiated by a No. 8 blasting cap, as well as with detonating cord and other initiating devices.**

Cast pentolite boosters, shown above, contain a mixture of pentaerythritol tetranitrate (PETN) and TNT. The typical formulation contains 50-percent PETN and 50-percent TNT, but some manufacturers’ brands may contain as high as 60-percent PETN.

Primers shown to the right are blasting-gelatin HE’s.

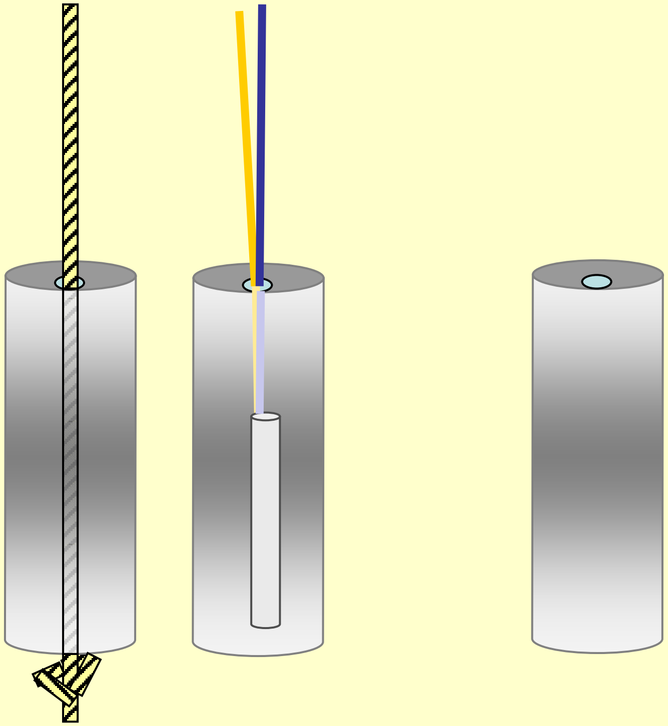
Boosters and Primers

What is the difference between a booster and a primer?

A primer is a booster (cast or packaged HE) in which a detonator has been inserted.

A booster, on the other hand, does not contain a detonator; rather, as its name suggests, it "boosts" the explosive energy in a column. Boosters are generally cap-sensitive HE's that are initiated by adjacent primers or detonating BA's.

Boosters may be used (1) in blastholes that are wet at the bottom, (2) when excess toe burden exists, or (3) within a hard geological strata.

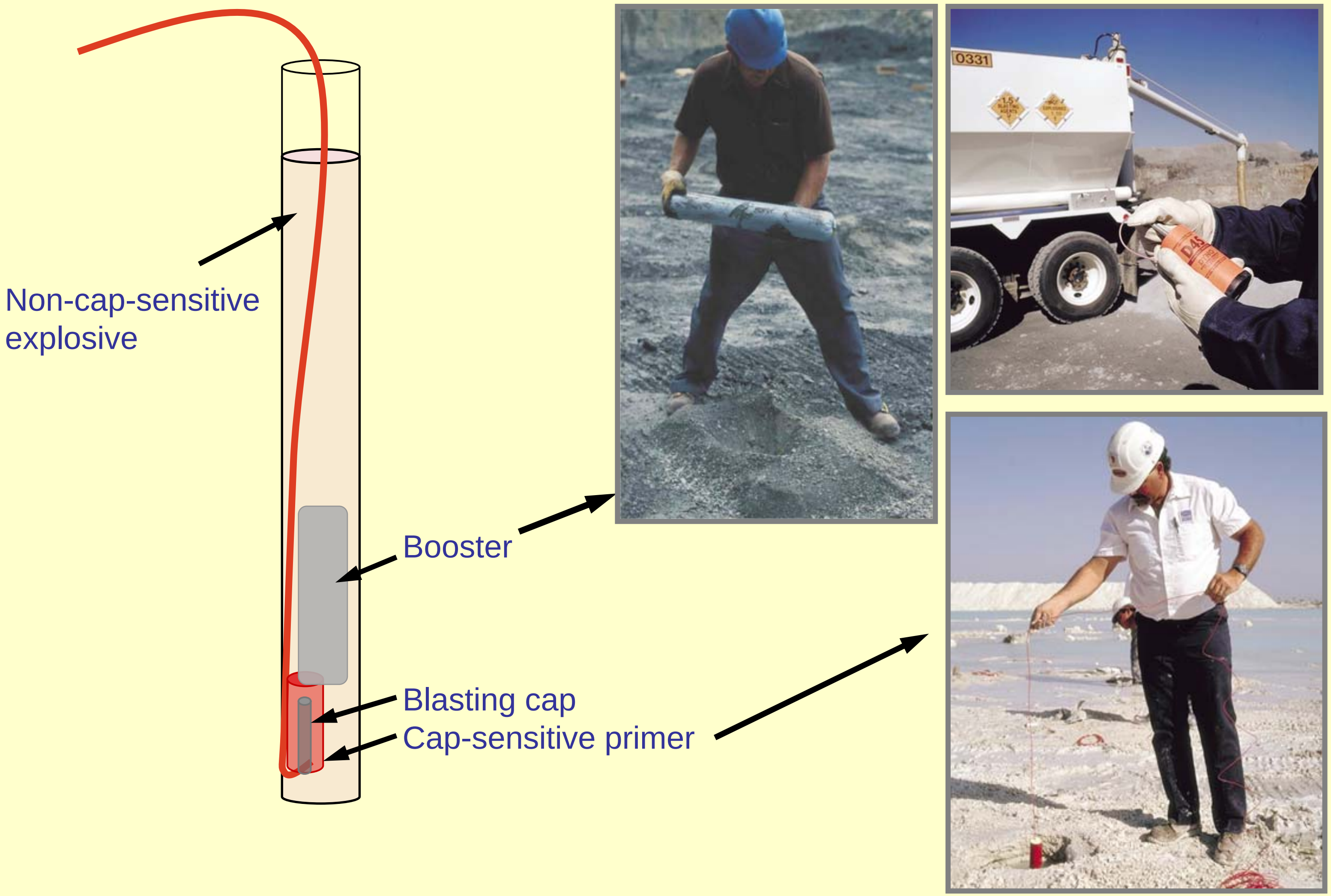


Primers contain a blasting cap or cord.

A booster has no cap or cord.

NOTE THAT THESE DIAGRAMS do not necessarily show correct methods to secure caps or cord; the diagrams are for definition purposes only!

Boosters and Primers



The Safe Handling of Boosters

Boosters are HE's, and, as such, they need to be handled with care:

- **ALWAYS** read and follow the warnings and instructions of explosives' manufacturers and suppliers.
- **ALWAYS** retire to a safe place and **WARN OTHERS** before initiation of explosives.
- **ALWAYS** rotate stocks. Use the oldest units in your inventory first. Age affects the integrity of detonators and other explosives devices.
- **ALWAYS** transport, store, and use cast boosters and all other explosives in accordance with all Federal, State, and local laws.

- **ALWAYS** dispose of or destroy cast boosters and all other explosives in accordance with approved methods. Consult the manufacturer or follow the IME statement of policy publications.
- **ALWAYS** evacuate personnel to a safe location away from possible detonation or explosion, in the event of a lighting storm during surface use of these products.
- **ALWAYS** keep explosive materials away from unauthorized persons.
- **ALWAYS** look for misfires and handle suspected misfires as you are directed by applicable local, State, and Federal laws and under the standards provided by the IME.

The Safe Handling of Boosters—continued

- **ALWAYS** ensure that the detonator or detonating cord is properly inserted into the booster and secured in such a manner to prevent it from falling out as the primer is being loaded into the blasthole.

- **ALWAYS** use the proper core-loading detonating cord to ensure reliable initiation of the booster selected. Consult the manufacturer for proper product selection.

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

- **NEVER** enlarge a hole in a cast primer or booster to accept a detonator or detonating cord.

- **NEVER** prepare more primers than are immediately needed.

- **NEVER** prepare primers in a magazine or near large quantities of explosives.

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

- **NEVER** force or attempt to force a detonator into a cast booster.

- **NEVER** use detonating cord for priming with any booster marked "**USE DETONATOR ONLY.**" Misfires could result.

Review Questions and Discussion

1. Cap-sensitive explosives are classified as:
    a. Wet blasting agents
    b. High explosives
    c. Low explosives
    d. Ammonium nitrate

2. Reddish-orange smoke after a blast signifies the presence of:
    a. Carbon monoxide
    b. Water vapor
    c. A good blast
    d. Oxides of nitrogen

3. What is a mixture of ammonium nitrate and diesel fuel oil called?

4. Ammonium nitrate is:
    a. An oxidizer
    b. A sensitizer
    c. A fuel
    d. Poisonous gas

5. True or false: the detonation energy of ANFO will not be lowered when it is loaded into wet blastholes.

Review Questions and Discussion—continued

6. The optimum mixture of ANFO contains what percentage of "AN" and what percentage of "FO"?

7. If you encounter blastholes that are wet, which product(s) should you use (list all that apply)?
   a. Blast powder
   b. 20-percent emulsion/80-percent ANFO blend
   c. 100-percent ANFO
   d. Emulsion

8. The detonation velocity of ANFO in large-diameter holes is:
   a. 5,000 ft/s
   b. 500 ft/s
   c. 14,500 ft/s
   d. 21,000 ft/s

9. The causes of reddish orange smoke include (list all that apply):
   a. Wet holes
   b. Lack of confinement
   c. Insufficient amount of fuel
   d. A shock compression of explosives that changes their densities

Answers

1. b. is correct.
2. d. is correct.
3. ANFO
4. a. is correct.
5. False.
6. 94-percent AN and 6-percent FO.
7. d. is correct.
8. c. is correct.
9. All apply.