EXPLOSIVES

By Robert M. Black.*

It is natural to associate explosives with destruction, but their use in construction and upbuilding has been a large factor in the history of civilization. They have been essential in making the excavations for many railroads, canals, and buildings, they have assisted in agriculture, they have made quarry work easy, they have limited conflagrations and they have made possible economical mining.

Primitive mines appear to have been surface accumulations of gems or minerals, which were loosened with pointed sticks. The ancients later used alternate applications of fire and water to loosen the valuable mineral, or rock containing it. Such methods could not produce a quantity of mineral sufficient to meet the growing demands. Nor did the best of the early methods penetrate beyond very shallow depths, unless the material happened to be exceptionally rich and easy to work. While there are some substitutes for explosives now used in a limited way in mining practice, still the history of mineral production shows the dependence of the industry on explosives. Increased use has brought about improvements in composition, in facilities for use, in safety and in cost, most of which development has taken place within comparatively recent times. Explosives are to be credited not only with the large production of mineral generally, but also with the entire production of certain minerals that occur under conditions rendering them difficult or impossible of winning otherwise. Practically all the coal mined in the United States is broken from the seam by the use of explosives.

The oldest explosive is believed to be gunpowder, but the date of its invention and the name of the inventor remain uncertain. A document still preserved at Florence, Italy, relating to the manufacture of cannon, refers incidentally to gunpowder. The date, February 11, 1326, marks the first unquestioned reference to the use of gunpowder in Europe. Roger Bacon, the English philosopher, who lived in the thirteenth century, writes of a mixture composed of saltpeter, charcoal and sulphur in proportions similar to those of gunpowder, "producing noise like thunder and flashes like lightning." It seems to have been regarded at that time as a curiosity, and its applications to useful work were unknown. There is some reason to refer the invention of gunpowder back to more ancient time, when, according to the views of some, the Chinese, Greeks and other races had substances resembling it, but the evidence is by no means conclusive.

DESCRIPTION OF EXPLOSIVES

An explosive is defined as a substance capable of extremely rapid decomposition into a relatively large volume of gases under the action of either heat or shock. Combustion is the union of any element with oxygen, a familiar example of which is the burning of wood, the carbon of the wood uniting with oxygen to form gases. The gases in this case are formed slowly, and have abundant opportunity to pass off into the atmosphere without disturbance. If the rate of formation of the combustion gases is rapid, and if the volume of such gases is much greater than can be contained in the space formerly occupied by the combustible substance, then the pressure on the inside of the space containing the gases is so great that the enclosing material is ruptured and fragments are thrown to varying distances. The pressure is further increased by the heat of combustion expanding the gases formed.

Gunpowder

The standard proportion of materials are 75 parts potassium nitrate, 15 parts charcoal and 10 parts sulphur. The charcoal contributes carbon, the saltpeter furnishes oxygen and the sulphur produces a temperature necessary for combustion. For use in guns potassium nitrate is preferred to sodium nitrate or Chile saltpeter, as it keeps drier, and, therefore in better condition for use after long periods of preservation.

Black Blasting Powder

For a blasting powder, either of the two saltpeters may be used, but the consideration of economy favors the sodium nitrate. Powders made from either saltpeter are known commonly by the name of black powder, or blasting powder, that containing potassium nitrate being usually designated by manufacturers as "A", and that containing sodium nitrate as "B". When sodium nitrate is used, the proportions of the mixture are slightly different, namely, 73 parts sodium nitrate, 16 parts charcoal, 11 parts sulphur. The difference is due chiefly to the fact that they oxygen content of sodium nitrate is greater than that of potassium nitrate. In each case, the intention is to provide just enough oxygen to consume the carbon and sulphur.

Blasting powder is marketed in granular form, "A" powder, Fig. 1, usually in seven different sizes, and "B" powder, Fig. 2, in the same number, each size being designated by one or more letters. In general, the sizes of "A" and "B" powders do not correspond, the "B" averaging larger than the "A".

The powder is packed in sheet steel kegs, usually of 25 pounds capacity, although the use of fibre for the material of the container is also in favor. The chief advantage of the latter is that it a nonconductor of electricity, and is, therefore, safer for transportation in cars hauled by electric locomotives. If the powder is received in metal containers, it may be transferred to fibre containers, provided with bail handles and designed specially for such transportation. The latter are known as electrical pails, and are used for other explosives, as well as blasting powder. The same material has been employed in making powder flasks

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for the individual miner, these being of the maximum capacity permitted by law, usually five pounds.

The sizes of powder are carefully separated at the factory, and grains of one size only are shipped in one container. The chief purpose of this precaution is to insure, as far as possible, uniformity in rate of burning. If grains of different sizes were mixed, the smaller grains would burn more quickly, and tend to throw the larger grains in an unburned or incandescent state out of the hole. Under some circumstances, the result would be only a waste of the larger grains, but if explosive gas were present, as is often the case in coal mines, the danger of igniting it would be very great. Another advantage of uniform sized grains is the standardizing of results, which makes possible the selection of powders suited to certain requirements. The grains are usually glazed with graphite to render them more impervious to moisture. Fine grained powders are quicker, and tend to shatter the material more, while coarse grained powders are slower and have more of a lifting effect.

Chlorate Powder

Oxygen may be obtained from other compounds beside nitrates, and many efforts have been made to adapt such substances to use in explosives. Some success has been attained with potassium chlorate (KCO_3), but the liability of this substance to explode on slight friction has prevented its general use. Methods have been devised, however, of restricting this tendency by mixing with certain other substances, such as starch, and the results have been satisfactory.

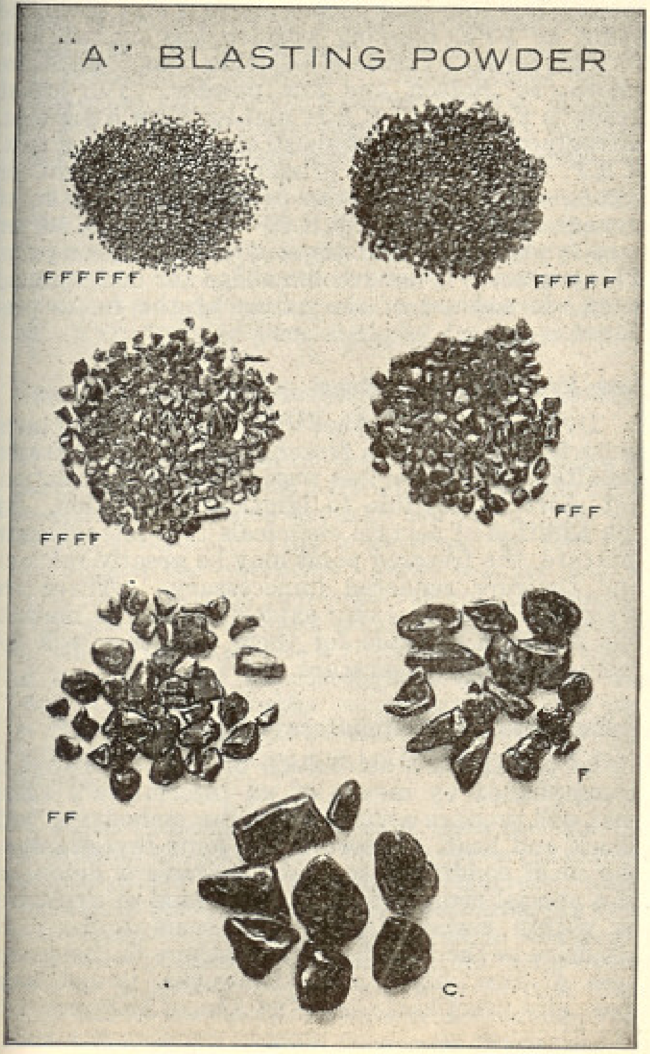


Fig. 1—Sizes of "A" Blasting Powder.

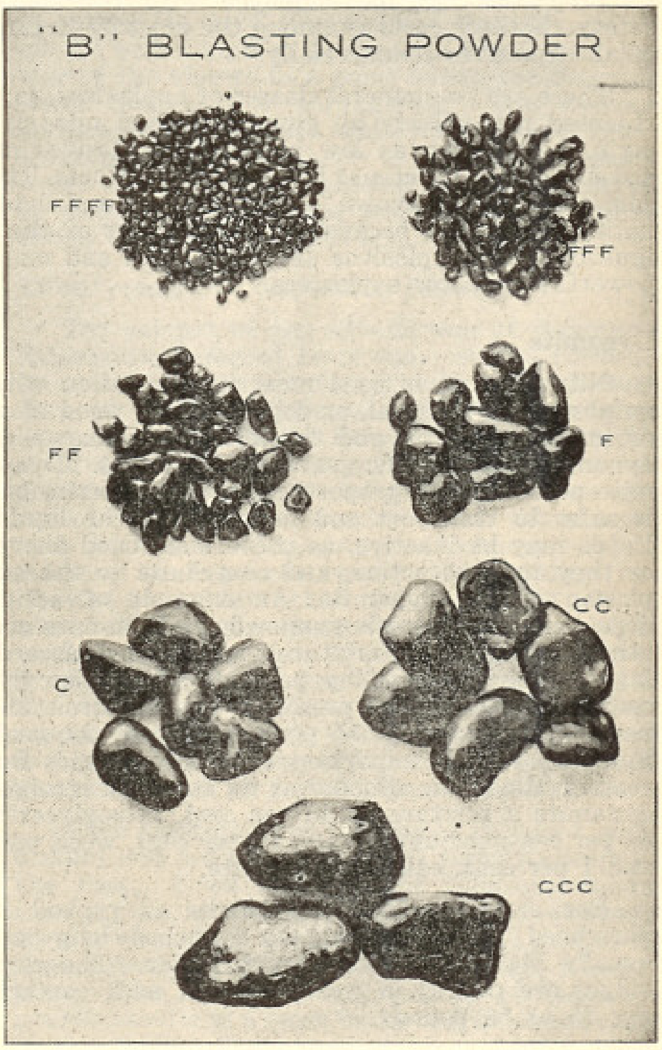


Fig. 2—Sizes of "B" Blasting Powder.

Nitroglycerin

Oxygen may be made to unite chemically with certain substances by treating the substances with nitric acid (HNO_3). The nitric acid is manufactured from either of the saltpeters, and contains the same quantity of oxygen as the saltpeter. One substance frequently treated with nitric acid for this purpose is glycerin, $C_3H_5(OH)_3$, the result of the nitration being a compound known as nitroglycerin, $C_3H_5(NO)_3$. In this process, sulphuric acid is first run into nitric acid, then gylcerin into this mixture, the heat of the reaction being dissipated by careful stirring and sometimes artificial cooling. The nitroglycerin formed is separated from the acid by pouring into cold water, and is then purified.

Nitroglycerin is a colorless, oily liquid with specific gravity about 1.6. It freezes at a temperature of about 55° F., and is evaporated by heating, but at 306° F. explodes by reason of the temperature alone. It is poisonous to the human system internally and externally, but the danger from contact poisoning diminishes with continued handling. It is exploded ordinarily by shock, and is very sensitive to shocks; therefore, is especially dangerous to handle. In the liquid condition, it is little used, but when associated with certain solid substances, its properties may be employed with reasonable safety Nitroglycerin is among the most important of all explosives commercially.

There are two general classes of explosives, represented respectively by gunpowder and nitroglycerin, and known as low and high explosives on account of the difference between their effects. The same classes are known as deflagrating and detonating explosives, because of the manner of their ignition. High explosives are more rapid and more powerful than low explosives.

Dynamite

Nitroglycerin is used most in connection with an absorbent material, or dope, such as wood meal or infusorial earth, and the mixture is known as dynamite. Its specific gravity is about 1.4. Dynamite possesses the properties of nitroglycerin, but is safer to transport and handle than the liquid. Dopes may be inactive, as those mentioned above, or they may be active, and contribute to the explosion of the dynamite. An example of active dope sometimes used is gunpowder. Dynamite and other nitroglycerin mixtures are graded according to their strength by percentages of nitroglycerin, or its equivalent, present in the mixture. The usual rainge is from 15 per cent. to 60 per cent. For purposes of comparison, the United States Bureau of Mines has adopted as its standard straight dynamite a mixture of 40 per cent. nitroglycerin, 44 per cent. sodium nitrate, 15 per cent. wood pulp and 1 per cent. calcium carbonate.

For commercial use, dynamite is packed in paraffined paper cartridges, 8 inches long and usually 1¼ or 1½ inches in diameter. The cartridges are packed in wooden boxes, each containing 25 or 50 pounds.

The products of combustion of 200 grams of standard dynamite are stated as follows:*

PRODUCTS OF COMBUSTION FROM 200 GRAMS OF THE EXPLOSIVE

	Grams.
Solid	79.7
Liquid (water)	14.5
Gaseous	88.4

Gaseous Products of Combustion

	Per cent. by volume.
Carbon dioxide	51.4
Carbon monoxide	5.0
Hydrogen	2.2
Methane	.3
Nitrogen	41.1
	100.0

Solid Products of Combustion

	Per cent.
Soluble (sodium carbonate)	79.43
Insoluble (calcium carbonate, trace of unburned carbonaceous matter, and carbonates and oxides of copper, iron, and tin)	20.57
	100.0

GASEOUS PRODUCTS OF COMBUSTION FROM 200 GRAMS OF THE EXPLOSIVE AND 12.4 GRAMS OF PAPER WRAPPER

	Per cent.
Carbon dioxide	27.3
Carbon monoxide	26.9
Hydrogen	18.0
Methane	.4
Nitrogen	27.4
	100.0

Guncotton

If cotton is treated with nitric acid in a manner corresponding to the treatment given the glycerin, there results a substance, guncotton, or nitrocellulose, which is highly explosive. The chemical process is essentially a replacement of the hydrogen in the cotton by nitrogen and oxygen, this providing the oxygen necessary for burning the substance with explosive rapidity. Another high explosive, similar to guncotton in its composition and manufacture, is nitrostarch, made by nitrating starch.

Blasting Gelatine

A solution of guncotton in nitroglycerin makes a gelatinous substance, known as blasting gelatine, which is an extremely quick and powerful explosive, inasmuch as the carbon that would be left after explosion of the cuncotton alone is consumed by the oxygen that would be left by the explosion of the nitroglycerin alone. The strength of blasting gelatine is rated at 100 per cent. The mixture of blasting gelatine with an absorbent dope is known as gelatine dynamite. Either form is considered to be especially suited to blasting under water. Grades of Gelatin Dynamite vary from 20 to 60%.

Judson Powder

Granulated nitro-powder consists of sulphur, nitrate of soda, and high-grade blacksmith's coal, melted together and broken up to a size about the same as FFF blasting powder and coated with nitroglycerin. Powders of this description are known as Judson and low powder. The lowest grade is designated R.R.P. and contains 5 per cent. nitroglycerine. The highest contains 20 per cent. R.R.P. should have a primer of 40 per cent. or stronger dynamite in the proportions of 1 lb. of dynamite to 25 lb. of R.R.P. Those above 10 per cent in grade can be detonated with a blasting cap. This explosive is not recommended for underground work, on account of the nature of the fumes produced.

Low Freezing Explosives

Dynamite and other nitroglycerin mixtures must be thawed when frozen, because in the frozen condition, they are less susceptible to detonation, but more susceptible to ignition by friction. By the addition of certain chemicals to a nitroglycerin mixture, the freezing point may be greatly reduced, and thawing rendered unnecessary. There are many such low freezing explosives on the market, but no claim is made for them that they will not freeze at any temperature.

Fulminates and Detonators†

In practice the detonation of high explosives is accomplished by means of an intermediate agent that will produce a violent impulse embodying both shock and heat. According to some investigators, the ideal condition would be to have a detonator of a special composition for each kind of explosive, as within certain limits some seem to be more sensitive to the heat factor and others to the sharpness of the shock. This, however, is not commercially practicable, and the aim of the manufac-

*Bulletin 15, U. S. Bureau of Mines, page 172.
†Charles S. Hurter, in Engineering & Mining Journal, Feb. 25, 1922.

turers has been to make an all-round satisfactory detonator.

Until recently fulminate of mercury has formed the basis of nearly all commercial detonators, and at present, in most of them, this compound is the main ingredient. Mixtures of fulminate of mercury with other compounds are made with the object of increasing its sensitiveness to ignition and also for increasing the volume and temperature of the gaseous products, to give a greater effectiveness. Detonating in its own volume, as it does, the effect of straight fulminate is too local. The compound most commonly used for the purpose noted is chlorate of potash.

Compounds of Fulminate and Chlorate

The chemical reaction involving fulminate of mercury and chlorate of potash for complete combustion of their products may be expressed according to the following equation:

$$3\ Hg\ C_2N_2O_2 + 2K\ ClO_3 = 6\ CO_2 + 6N + 3\ Hg + 2\ KCl$$

Molecular weights are 852.12 for the fulminate and 245.2 for the chlorate. At the detonation temperatures of fulminate of mercury the oxides of mercury cannot exist.

According to this reaction 852.12 parts of fulminate of mercury are mixed with 245.2 parts by weight of chlorate of potash to bring about complete combustion. This proportion can be expressed approximately as 78 per cent. of fulminate and 22 per cent of chlorate. The mixtures used in detonators have varied from 95 per cent. fulminate of mercury and 5 per cent chlorate of potash to 80 per cent fulminate and 20 per cent chlorate.

According to tests made by the Bureau of Mines (Technical Paper No. 125, "The Sand Test for Determining the Strength of Detonators") several years ago, the 80—20 mixture creates a more effective detonating impulse than the 90—10, the 95—5 mixture, or even straight fulminate.

Completeness of Explosion Depends On Amount of Explosive Set Off At Start

The completeness of the explosion and the distance it travels through the charge depends on the amount of explosive actually set off at the start by the detonator. This is governed by two facts, the size of the detonator charge and its distribution. The first is self-explanatory. By using a small-diameter detonator which extends the charge, the amount of explosive acted upon by the detonator is increased and the consequent detonation wave started off with greater intensity. Another point is that no explosive attains its maximum rate of detonation or violence instantly in the first layers affected.

Even fulminate of mercury does not start its detonation at full speed. This, however, is attained quickly after the detonation is started. Consequently, in the smaller-diameter detonators, a larger percentage of the fulminate charge is exerting its maximum possible effect, owing to its being extended over a greater length, which gives it a chance to attain its maximum violence of detonation, which is not the condition with the larger-diameter blasting cap containing the same charge.

It is true that fulminate of mercury attains its full velocity more quickly in a large-diameter capsule, but with an explosive so sensitive this point is negligible when compared with the better results obtained from the explosive detonated by having a larger amount of this explosive brought under the direct influence of the fulminate. Also, it is possible with fulminate of mercury, as with all the other high explosives, to reduce the diameter of the charge to a point where the detonation wave cannot pass through it. The necessary diameter for good fuse limits the manufacturer to a minimum inside diameter of 0.221 in. for blasting caps. The making and placing of a substantial plug in electric blasting caps necessitates a minimum inside diameter of 0.260 in.

Effectiveness of Composition Detonators

The subject of the effectivness of composition detonators, referred to in some of the Bureau of Mines reports as reinforced detonators, is therefore of pertinent interest. It has been shown beyond question by the Bureau of Mines and other investigators that certain nitro-substitution compounds and nitrated carbohydrates, such as nitrovene, tetryl, tetranitroanilin, and nitromannite, each with a small quantity of fulminate-chlorate mixture as a primer, make, if anything, more efficient detonators than fulminate and chlorate alone. The compounds named must be kept in close confinement if they are to exert their full explosive force, and to obtain this the small amount of fulminate used as a primer is placed in an interior copper capsule which is seated firmly on the charge. In fact, good confinement is necessary for detonator charges as well as for all other explosives.

Some blasting caps that have appeared on the market will not detonate unless rightly crimped on the fuse. Even the straight fulminate-chlorate caps give a better test and improved detonation results when they are tightly fastened on the fuse than when only partly crimped or held loosely in place. The lighter specific gravity of these compounds results in a more bulky and extended charge in the shell, with a greater amount of explosive upon which a direct action is exerted as a result. Thus the detonation wave in the main explosive charge is started off with a greater intensity and a better explosive action, and more satisfactory results are obtained. This type of detonator is being received with favor, and with later perfections that will probably be evolved may largely if not completely replace the present-day fulminate-chlorate blasting caps.

Comparative Strengths of Blasting Explosives*

In the course of its investigations of blasting explosives, the U. S. Bureau of Mines (Bull. 48) has made tests to determine the potential energy, the disruptive effect and the propulsive effect of some of the explosives in common use. The potential energy was measured by means of the bomb calorimeter in water. The disruptive effect was measured, using the Mettegang recorder, detonating fuse, Trauzl lead blocks and small lead blocks. The propulsive effect was measured in the Bichel pressure gage and by means of the ballistic pendulum. The tabulated results are given herewith, to-

*Eng. and Min. Journal.

gether with the approximate composition of typical examples of the various explosives. The percentages figured are rated against the effect of 40% straight nitroglycerin dynamite taken at 100 per cent.

The figures are fairly consistent with general practice, and it is believed that the classification will serve as a useful guide for comparing the practical value of explosives. It is worthy of note that the potential energy of 40% strength ammonia dynamite and of 40% strength gelatin dynamite, that is, the theoretical maximum work that these explosives can accomplish, is higher than that of 40% straight nitroglycerin dynamite, but that the disruptive and propulsive effects, which represent the useful work done as shown by actual tests, are less. Accordingly, straight nitroglycerin dynamite is more economical for general use in blasting operations if the conditions and character of the work are such as to permit its use; nevertheless, the ammonia dynamite and the gelatin dynamite are more efficient and economical for certain kinds of work that require explosives having a large propulsive effect and a comparatively small disruptive effect. For example, in blasting soft rock, 40% straight nitroglycerin dynamite, which has a very high percussive force, may be too quick in action, whereas the ammonia dynamite or the gelatin dynamite having practically the same heaving and pushing action and less percussive force will be more suitable. The tests also show that 60% strength low-freezing dynamite is not quite equivalent to the 40% straight nitroglycerin dynamite. It is worthy of note that black blasting powder has little disruptive effect, only about one-third that of granulated nitroglycerin powder.

Means of Firing

The simplest means of firing is a squib, a thin paper tube, about 6 inches long, one end of which contains a core of meal powder and the other a slow match. After the cartridges are in position, a copper, or copper tipped, needle a quarter of an inch in diameter is pushed into the outer end of the charge, as shown in Fig. 9. About the needle the clay tamping material is packed with a wooden bar. The needle is then withdrawn, leaving a passage of its own dimensions from the outside of the hole to the powder. Into this hole the squib is placed. After the match is lighted, Fig. 10, a brief interval elapses before the squib is projected forward like a rocket and its flame ignites the powder.

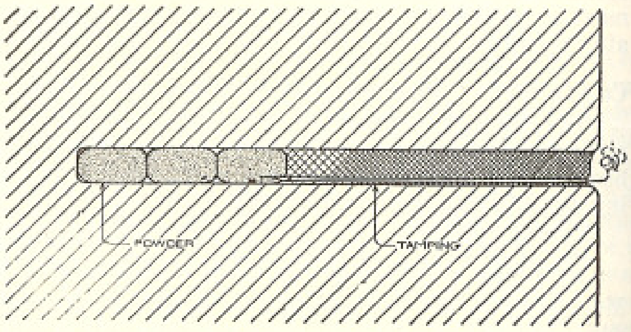


Fig. 10—Drill Hole, Showing Squib Lighted.

The squib has the advantage of cheapness, and usually of time saving, but is uncertain on account of possible caving of the needle hole. Another objection is the danger of igniting explosive gases that may be present.

To make the passage for the squib more substantial, a blasting barrel, Fig. 11, is sometimes used, which is a section of pipe of suitable length and diameter. The squib is used in the same manner as when the passage is formed by a needle. The blasting barrel is usually recovered after an explosion and used again.

A second means of igniting a charge of powder is fuse, generally called safety fuse, Fig. 12, which

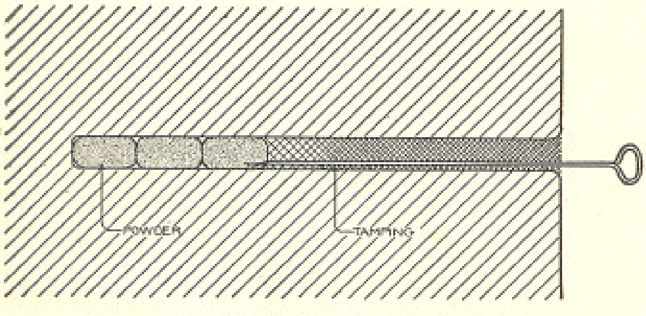


Fig. 9—Drill Hole, Showing Needle in Place.

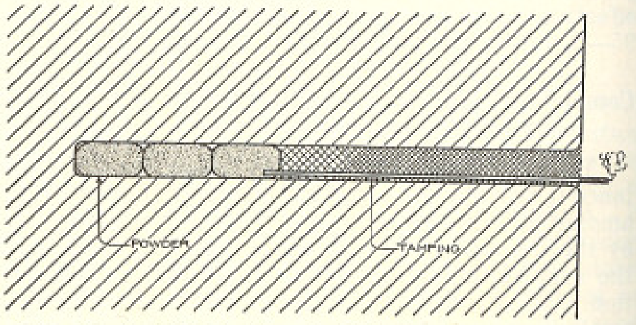


Fig. 11—Drill Hole, Showing Blasting Barrel in Place.

TYPICAL ANALYSES AND STRENGTHS OF COMMON BLASTING EXPLOSIVES*

	Percentage Composition									Percentage Strength		
	Nitroglycerin	Combustible Material	$NaNO_3$	ZnO $CaCO_3$ $MgCO_3$	Nitro-substitution Compounds	NH_4NO_3	Nitrocellulose	S	C	Potential Energy	Disruptive Effect	Propulsive Effect
Straight nitroglycerin dynamite, 30%	30	a17	52	1	..	..	..	..	..	93.1	84.1	96.8
Straight nitroglycerin dynamite, 40%	40	b15	44	1	..	..	..	..	..	100.0	100.0	100.0
Straight nitroglycerin dynamite, 50%	50	b14	35	1	..	..	..	..	..	111.0	109.2	107.4
Straight nitroglycerin dynamite, 60%	60	b16	23	1	..	..	..	..	..	104.0	119.8	114.9
Low-freezing dynamite, 40%	30	b15	44	1	10	..	..	..	..	.....	.....	.....
Low-freezing dynamite, 60%	45	b16	23	1	15	..	..	..	..	60.2	93.5	91.2
Ammonia dynamite, 40%	22	a15	42	1	..	20	..	..	..	101.8	67.9	99.1
Gelatin dynamite, 40%	33	a13	52	1	..	..	1	..	..	105.7	78.4	95.8
Granulated nitroglycerin powder, 5%	5	c35	60	..	..	..	..	..	..	67.6	21.6	53.3
Black blasting powder	..	...	73	..	..	..	..	11	16	71.6	6.8	58.6

a Wood pulp, four and sulphur.
b Wood pulp only.
c Sulphur, coal and resin.

*Eng. and Min. Journal.

is a train of fine powder enclosed in hemp or cotton, covered with one or more layers of tape for the purpose of waterproofing. When lighted at one end, flame travels along inside the tube to the other end, where, if placed within the charge, it ignites the powder. Fuse usually burns at the rate of $1\frac{1}{2}$ to 2 feet per minute, and the rate is specified by the manufacturer. The blaster is thus enabled to esti-

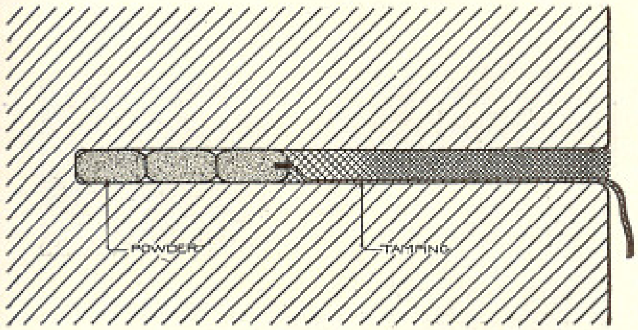


Fig. 12—Drill Hole, Showing Fuse in Place.

mate the length of fuse required to enable him to reach a safe place, and by cutting a fuse to proper length, may take more time than a squib would allow. The rate of burning cannot be guaranteed, however, as fuse may be subjected to injury that would interrupt the train of powder. It is advisable to make tests of the fuse in use for rate of burning. Failure of a charge to explode may be only temporary, and the flame may be started again of its path after an interval. Many lives have been lost by returning prematurely to investigate a delayed ignition. Fuse is prepared for conditions varying from dry to submarine, the difference being mainly in the character of taping. The uncertainty of fuse and its tendency to flame are serious objections.

A third method of ignition involves the use of detonators. It may be applied to low explosives, but is most used in firing high explosives and permissibles, and is the only approved method of firing the latter. A detonator is distinguished from an

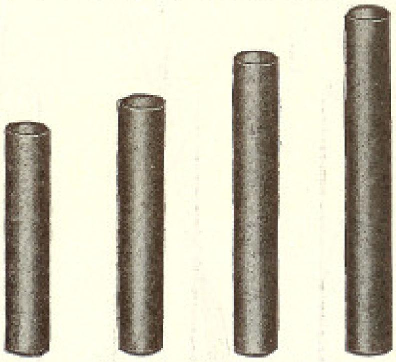


Fig. 13—Detonators.

electric detonator. The former is commonly called a blasting cap. A blasting cap (or detonator proper), as shown in Fig. 13, is a copper cylinder

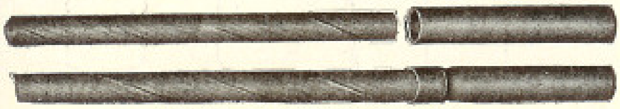


Fig. 14—Fuse and Detonator.

about a quarter of an inch in diameter and from $1\frac{1}{4}$ inches to $1\frac{7}{8}$ inches long, filled for about one-third to one-half its length with mercury fulminate or a mixture of mercury fulminate with potassium chlorate. The sensitiveness and other qualities of these substances have already been described. The other end of the detonator is left open for inserting the end of a fuse, which, when lighted, conveys flame directly to the mercury fulminate or other composition. The ignition of this substance produces a shock that is ample to detonate completely the charge of high or permissible explosive. In the attachment of fuse to blasting cap, Fig. 14, it is desirable to have a tight fit, in order to maintain their relative position, but not so tight as to break the powder train inside the fuse. The best and safest means of attaching is a crimper designed for the purpose. The crimper is often combined with a fuse cutter in one tool.

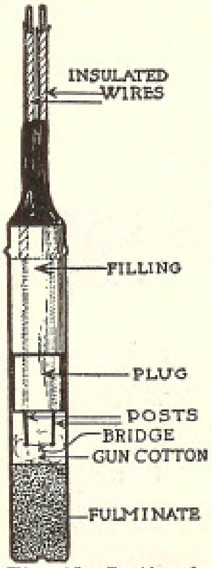


Fig. 15—Sectional View of Electric Detonator.

An electric detonator, or electric blasting cap, serves the same purpose as the detonator or blasting cap used with fuse, but is so constructed that it can be fired by discharging an electric current through it. It consists, as shown in Fig. 15, of a copper shell, containing at its inner end the charge of mercury fulminate, followed sometimes by guncotton, next a waterproof plug and at the outer end a quantity of filling material. Insulated copper wires enter the cap and traverse the filling material and plug, terminating in the fulminate or guncoton. The ends, or posts, of the copper wires are connected by a platinum bridge, which is heated to incandescence by the electric current, thus exploding the charge. Detonators, whether electric or not, are designated by numbers, each number representing a different strength. No. 6, for example, contains 1.00 gram of the charge.

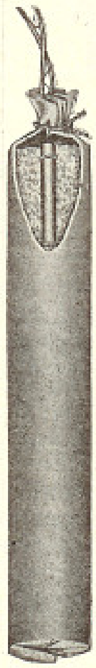
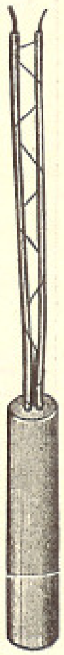


Fig. 17 Primer with Electric Detonator.


Electric Squib (Actual Size) Fig. 16.

An electric squib, Fig. 16, has been designed to replace the ordinary type of squib when blasting powder is used. It is a paper shell, containing a composition that flames when the electric current passes through it, and thus ignites the blasting powder. It is instantaneous, avoids the fumes that would come from an ordinary squib and is safer.

If it is desired to fire several shots in succession, detonators may be used that are provided with different lengths of a slow burning composition and are all connected in one electrical circuit. Thus, the order of shots and the time between any two consecutive shots may be arranged at will, only one electrical impulse being required for ignition of all.

Primer

In the use of high or permissible explosives, only one of the cartridges, usually the outer one of a charge, is in direct contact with a detonator. This cartridge is known as the primer, Fig. 17. The preparation of the primer is shown in Fig. 18.

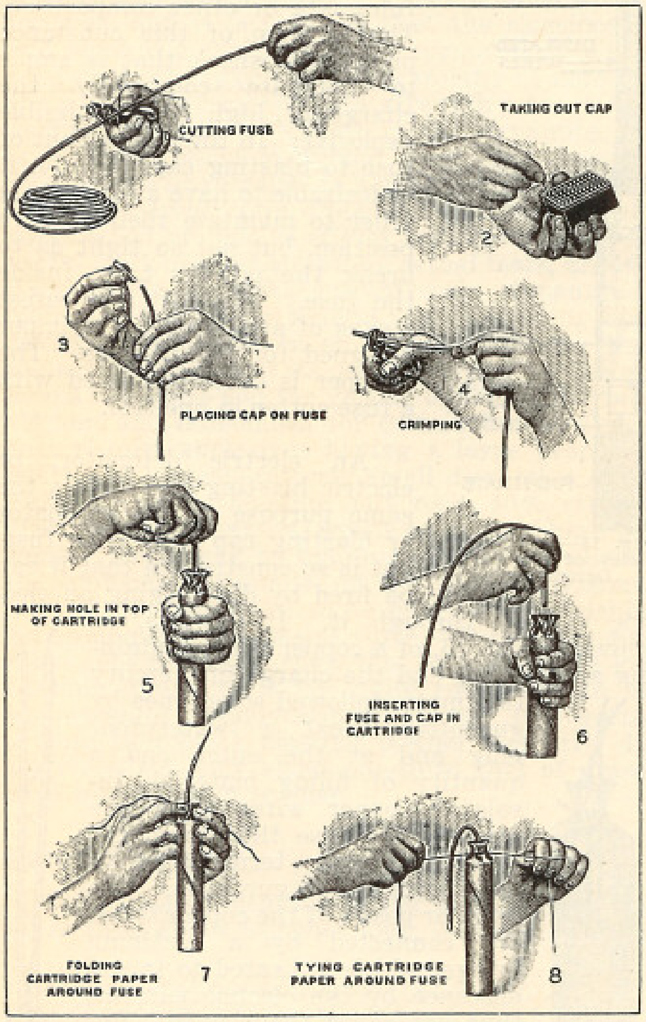


Fig. 18—Priming a Cartridge at the End.

After the fuse has been inserted into the end of the detonator and the latter crimped on the fuse, the cartridge wrapper is unfolded at one end and a hole is punched in the end of the cartridge by means of a wooden stick. The detonator is imbedded in the explosive material as far as the crimping. Then the loose paper is folded about the fuse and tied with a string.

Another method, Fig. 19, involves the punching of a hole diagonally in the side of the cartridge and inserting in it the detonator, binding the fuse to the outer surface of the cartridge with a string. This method is not so generally accepted, because of the liability of damage to the fuse through abrasion or bending, also because the greatest shock from a detonator is in line with its axis and away from the fuse or wires. The method of passing fuse entirely through a cartridge is a dangerous one, since bends or breaks may thus occur in the fuse, and the explosive may be burned, instead of detonated.

When electric detonators are used, the primer is prepared similarly, with detonator either in the end or side. Some users recommend the side method for electric detonators, but the practice is

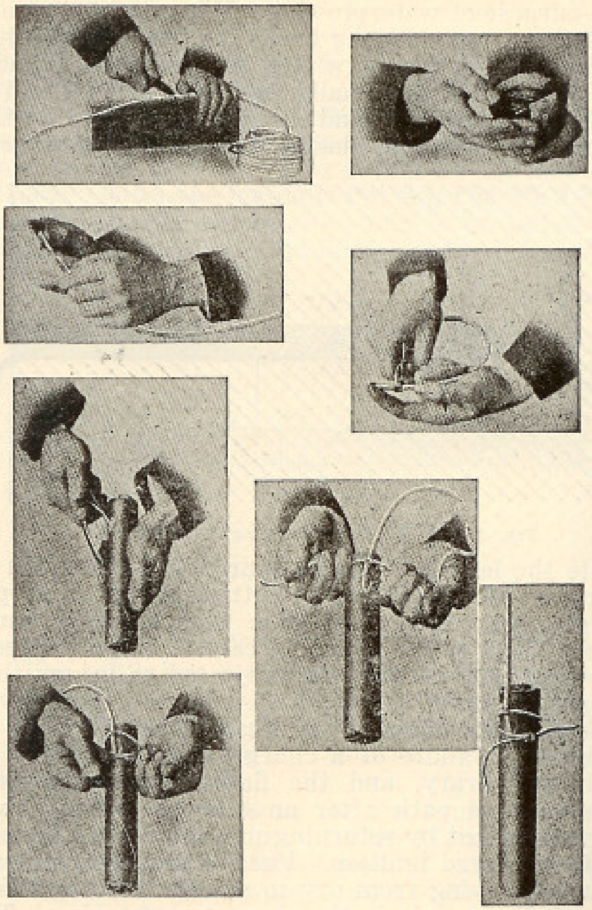


Fig. 19—Priming a Carrtidge at the Side.

by no means universal. A method that has been recommended for making a primer with electric detonator is shown in Fig. 20. The strength of the

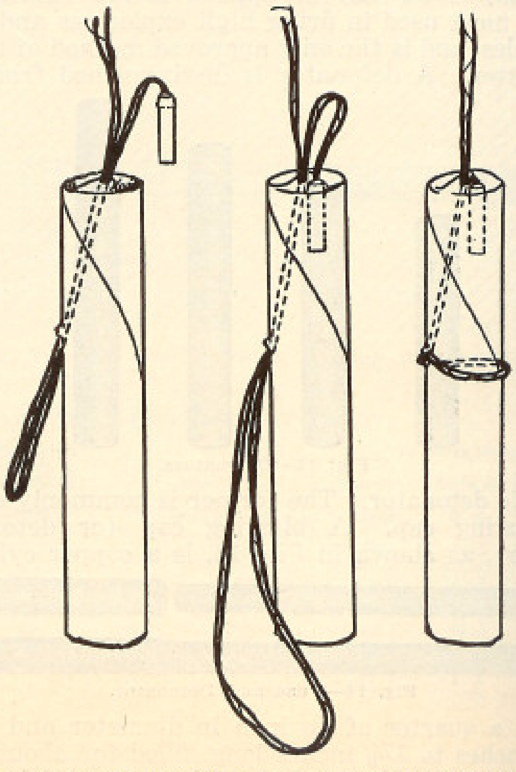


Fig. 20—Method of Priming with Electric Detonator.

detonator should be adapted to the work required. One too strong is better than one not strong enough. The use of No. 6 or stronger detonators is recommended for firing permissible explosives. Tests show that explosions are quicker and more complete, and consequently a smaller volume of poisonous gases is generated when such detonators are used. Also, unfavorable conditions, such as age of the explosive, are less effective.

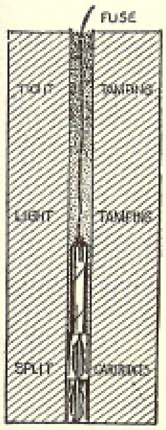


Fig. 21—Section of a Charged Drill Hole.

Tamping

With the primer properly prepared and placed in the hole outside of the other cartridges, damp clay or other incombustible material is tamped in upon the charge and around the fuse or electric wires extending to the mouth of the hole. The first six inches or so of tamping should be comparatively loose, in order to avoid disturbing the charge and detonator, but the remainder should be packed firmly, since the explosive gives better results when the resistance of the material in the drill hole is greater. A longitudinal section of the hole is shown in Fig. 21.

Electrical Method of Firing

The method of firing shots electrically has many advantages. First of all, it is safer. The charge can only be ignited by the person who controls the electric current, and he does not incur the risk so common with fuse or squib of ignition before he has reached a safe place. Delayed ignition is practically unknown when electricity is used. The danger of igniting gas or dust from squib or fuse flame is absent. Fumes of burning fuse are eliminated. Several shots may be fired simultaneously, thereby increasing the effect over that from firing the same shots separately. Electrical detonation of the explosive is found to be more complete and efficient.

Electric detonators may be obtained with wires from 4 feet to 20 feet in length. In any case, the wires should be long enough to extend at least a few inches out of the drill holes. At their ends good electrical connection is made to copper leading wires, which in turn are connected to the poles of the blasting machine. Leading wires may be two single wires or one duplex cable. In either case, they are thoroughly insulated. To connect the electric detonators in adjacent holes, when several are to be fired simultaneously, a smaller wire, known as connecting wire, is used, and the detonators are connected in series, as shown in Fig. 22. By this arrangement, the firing of all the detonators is assured, if one is fired.

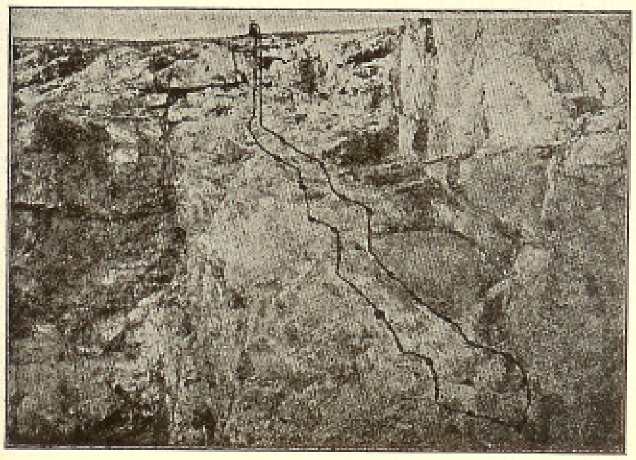


Fig. 22—Blasting Circuit Connected in Series.

The electric current necessary is usually generated with a blasting machine, often called a battery. The machine is essentially a dynamo, in which the input is the blaster's physical energy and the output is electrical energy. The average size of blasting machine for underground use stands about 15 inches high, weighs 20 to 25 pounds and has a capacity for firing 20 to 30 electric detonators simultaneously. Views of a typical two-post machine are shown in Fig. 23. An armature, B, is set between two electro-magnets, A. A rack bar, the handle of which extends above the top of the box, meshes with a pinion, C, on the revolving armature shaft. When the rack bar is pushed down vigorously, a current is generated by the revolution of the armature between the electro-magnets. The strength of the current accumulates until it reaches a maximum when the lower end of the rack bar is at the bottom. At this stage, the rack bar presses down the contact spring, the circuit through the magnets is broken and the current is discharged through the posts at the top, to which are attached the leading wires.

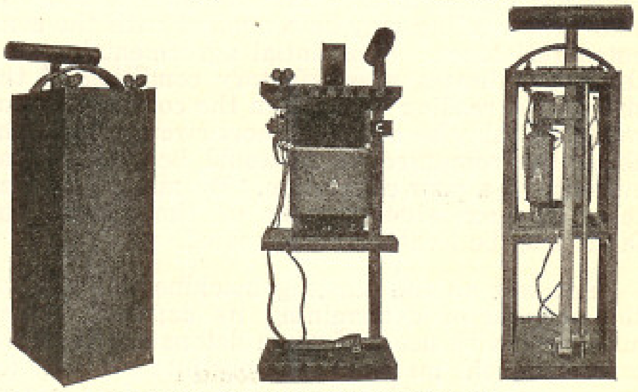


Fig. 23—Two-Post Blasting Machine.

Both larger and smaller blasting machines are on the market. A small one, designated as a pocket machine, Fig. 24, weighs only 4½ pounds, and has a capacity of three detonators. The smaller size is especially convenient because of its easier portability, and its capacity is equal to the ordinary requirements. Its general principles of construction and operation are the same as those of the larger machines. The handle is not pushed down for firing, as in the other types, but is turned about it axis with a vigorous twist. The fact that the handle is detachable makes the machine somewhat safer from unauthorized use.

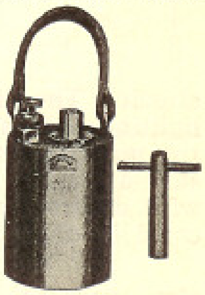
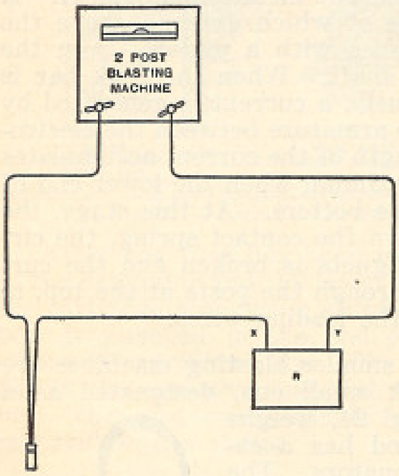


Fig. 24—Pocket Blasting Machine.

When blasting machines are used for firing, there are two tests necessary to make in order that the best results be obtained. One test is for the condition of the circuit, the other for the efficiency of the machine.

The test on the circuit is made with a galvanometer, preferably one of pocket size, designed expressly for this purpose, which consists essentially of a magnetic needle and a dry cell battery, so weak that it incurs no risk of firing a detonator. The resistance of the circuit may be computed, knowing the resistance of the detonators and of the wire used. It may also be taken from tables prepared for the purpose. When the terminals of the system of wiring are connected to the posts of the galvanometer, the needle is deflected through an angle varying inversely as the resistance. Since the scale is graduated to measure the resistance in ohms, the reading may be compared with the computed resistance. Substantial agreement between the two indicates a satisfactory condition of the circuit. A reading lower than the computed value would probably be due to a short circuit, while one above the computed value would be regarded as evidence of a poor connection. By making similar tests on successive portions of the circuit, the faults may be located and remedied.

The test on the blasting machine is made for the purpose of determining its capacity, which may vary with use. If more detonators than the capacity of the machine were put into a circuit for firing simultaneously, some would not fire, or perhaps none would fire. The instrument used for the test is a rheostat, which consists of a number of coils of wire, each with a known resistance, so arranged that any one or more can be connected into an electrical circuit. In making the test, as shown in Fig. 25, coils of the rheostat, R, with resistance equal to that of a certain number of electric detonators are wired into a circuit with a blasting machine and a single detonator. If the machine is now operated in the usual way, the consumption of current is the same as if all the detonators were actually in the circuit. The firing of the single detonator, or the lighting of a lamp in its place would indicate that the machine had a capacity at least equal to the sum of all the resistances. By successive trials with different resistances, the maximum capacity could be found.



Resistance Table—How To Use

The following table gives the resistance of various firing devices, singly and connected in series. The table of resistances shows the resistance of a single detonator only. The total resistance of a number of detonators is obtained by multiplying the resistance of one detonator by the total number that are connected in series. It the detonators are connected in other ways, the total resistance of the circuit must be computed by the ordinary methods applying to parallel or parallel series connections.

TABLE OF RESISTANCE IN OHMS OF ELECTRICAL FIRING DEVICES

Length of Wires of Electric Firing Devices in feet	Regular Copper Wire Electric Blasting Caps and Duplex Copper Wire Electric Blasting Caps	Submarine and Waterproof Electric Blasting Caps with Enameled Copper Wires	Electric Blasting Caps Copper Wire Only	Delay Electric Blasting Caps, Delay Electric Igniters and Electric Squibs with Copper Wires	Electric Blasting Caps with Iron Wire	Electric Squibs and Delay, Electric Igniters with Iron Wire
4	1.255	1.255		0.935	2.093	1.857
5					2.261	2.000
6	1.343	1.343		1.000	2.448	2.261
8	1.439	1.439		1.068	3.000	2.529
10	1.500	1.500		1.143	3.280	3.000
12	1.608	1.608		1.206	3.690	
14	1.679	1.679		1.272		
16	1.727	1.727		1.325		
18	1.803	1.803		1.400		
20	1.857	*1.479	1.479	1.459		
22	1.913	1.521'	1.521	1.521		
24	1.970	1.564	1.564	1.586		
26	2.030	1.631	1.631	1.655		
28	2.093	1.679	1.679	1.727		
30	2.158	1.727	1.727	1.777		

*Submarine or waterprof electric blasting caps have 22 gage wires up to and including 18 ft., 20 ft. Longer wires are 20 gage.

TABLE OF RESISTANCE OF COPPER LEADING AND CONNECTING WIRE IN OHMS PER 1000 FEET.

No. 8 Brown & Sharpe Gauge	.6271 Ohms	Usual size for power and lighting circuits.
No. 10 Brown & Sharpe Gauge	.9972 Ohms	
No. 12 Brown & Sharpe Gauge	1.586 Ohms	
No. 14 Brown & Sharpe Gauge	2.521 Ohms	Standard gauge for leading wire.
No. 16 Brown & Sharpe Gauge	4.009 Ohms	Sometimes used for short leading wire.
No. 18 Brown & Sharpe Gauge	6.374 Ohms	
No. 20 Brown & Sharpe Gauge	10.14 Ohms	Connecting wire.
No. 21 Brown & Sharpe Gauge	12.78 Ohms	
No. 22 Brown & Sharpe Gauge	1612 Ohms	Standard size for copper wire Electric Firing Devices.

Each foot of electric blasting cap wire doubled (2 wires) has a resistance of .032 ohms. The bridge of each electric blasting cap has a resistance of 1.10 ohms. The bridge of the electric squibs, delay electric blasting cap and delay electric igniter has a resistance of .859 ohms.

Determining Resistance of Blasting Circuit Connected in Series

To determine the resistance of any blasting circuit where the electric firing devices are connected in series, multiply the resistance of one firing device by the number in the circuit. Add to this the resistance of the leading wire and the connecting wire, and the result will be the total resistance of the circuit.

For example, if in a given blast 50 electric blasting caps with copper lead wires 20 feet long are used, also 100 feet of No. 20 Connecting Wire and 500 feet of No. 14 Single Leading Wire (or 250 feet of Duplex Wire), the total resistance would be found in the following manner:

One electric Blasting Cap with 20 ft. copper wire has resistance of 1.857 ohms. 50 of said caps have resistance of ....92.85 Ohms
1000 feet of No. 20 Connecting Wire has resistance of 10.14 ohms. 100 feet has resistance of....... 1.014 Ohms
1000 feet of No. 14 Gauge Leading Wire has resistance of 2.521 ohms. 500 feet has resistance of... 1.26 Ohms
The total resistance of the entire circuit would be..95.12 Ohms

When exceptionally long lengths of leading or connecting wire are used in blasting circuits, the resistance should be computed and added to that of the electric detonators to guard against overloading the blasting machine.

Cordeau

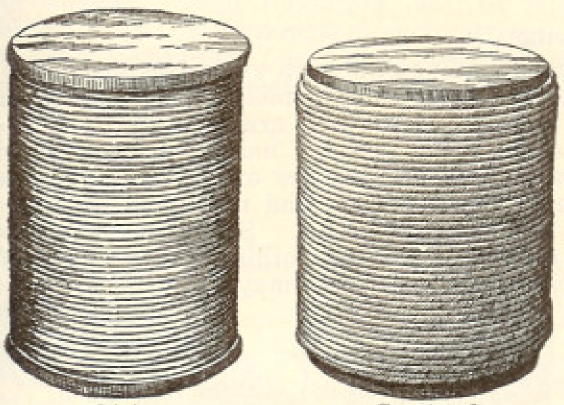
Cordeau or detonating fuse is a device for detonating explosive charges and within recent years has come into general use in connection with large, deep churn drill holes.

Cordeau is a small lead tube, about the same diameter as triple tape fuse, filled with Trinitro toluene, or T. N. T., which has a velocity of detonation of about 17,000 feet (more than 3 miles) per second. In other words, a piece of cordeau 17,000 feet long, if detonated at one end, will explode throughout its entire length in about one second. It is now used principally in deep well-drill blast holes and similar large blasts.

In spite of the great velocity and strength of the detonation of cordeau, it is very insensitive and cannot be exploded by hammering, pinching or burning. It is, therefore, safe to handle and load. It is exploded in actual use by means of blasting caps, electric blasting caps or by detonating dynamite.

The extreme violence of the explosion of cordeau is sufficient to detonate high explosives lying alongside it in a bore hole.

Cordeau is furnished either with the plain lead covering or with the lead covering surrounded with a second covering of cotton cord, the first being



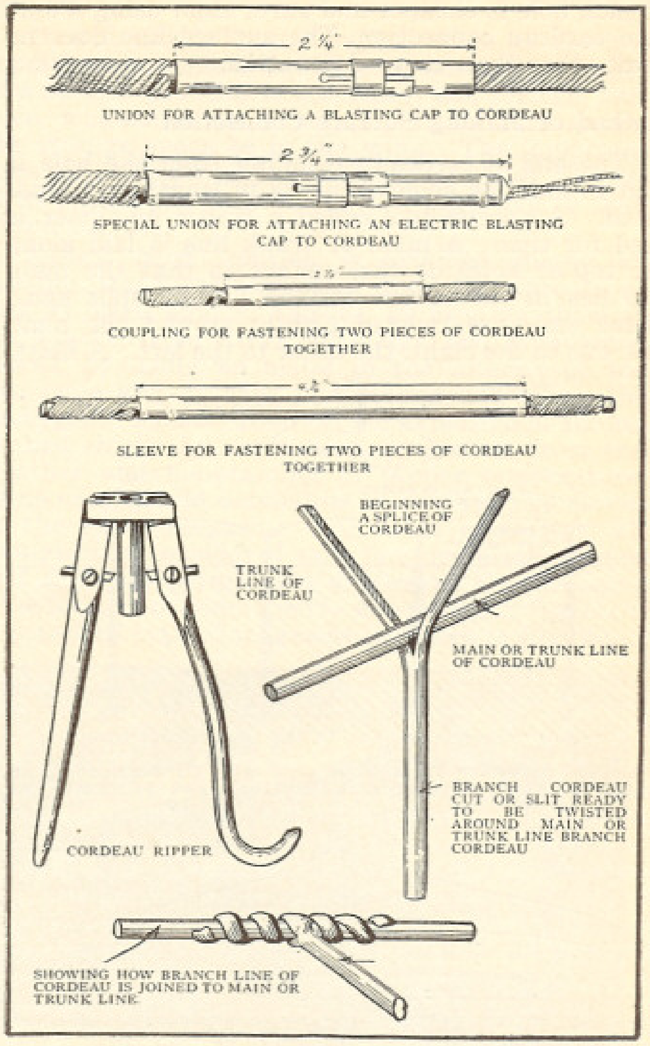
Plain Countered
Spools of Cordeau

called plain and the second countered. Countered cordeau is more resistant to abrasion of tamping materials.

Cordeau is shipped on spools containing from 100 feet to 500 feet each, not necessarily all of one length, the exact length of each piece being specified on the spool head. The first number shown represents the length in feet of the cordeau which would be first removed from the spool, the next number the second length, and the other number, if any, the third length.

Cordeau Accessories

Several accessories are needed when using cordeau. When it is exploded by means of a blasting cap and safety fuse, a "Union" is used to hold the blasting cap firmly in place; when an electric blasting cap is used a "Special Union" is used as shown in sketch herewith.

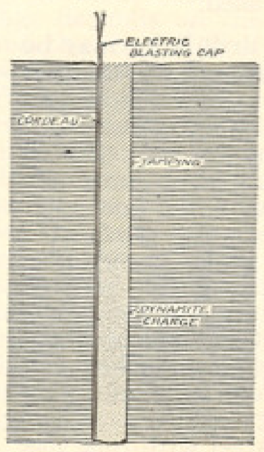


For splicing two lengths of cordeau together a brass coupling is used. A longer sleeve for making a stronger splice is shown in the sketch.

The Cordeau Ripper is a special tool for ripping or splitting the cordeau covering at the end when making connections to a surface main line for a branch or bore hole line as described later.

Loading a Hole with Cordeau

The end of the cordeau is tied to or laced through a dynamite cartridge and it is allowed to run off the spool until the cartridge reaches bottom and the cordeau extends full length of the hole. The rest of the charge is loaded in the usual manner. If there is water in the hole, the end of the cordeau should be sealed by hammering the lead together. When the hole is tamped, the cordeau is cut allowing six inches to extend above the collar of the hole. An electric blasting cap is attached to the end of cordeau at each hole by means of a brass union made for the purpose. Then the electric blasting caps are connected up and fired in the usual manner. The use of an electric blasting cap

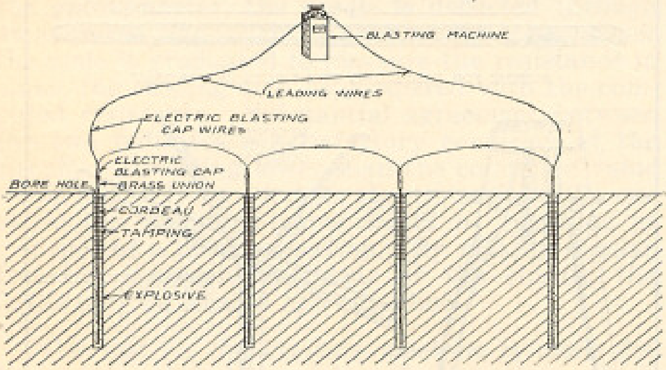


Showing location of Cordeau, reaching to bottom of bore hole.

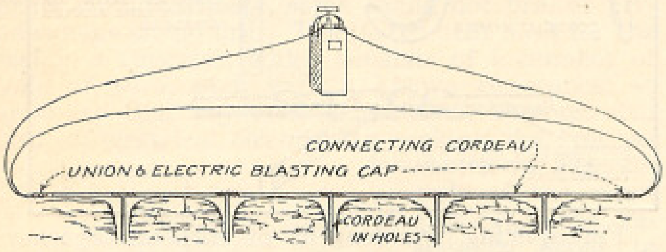
at each hole is cheaper and surer than using a surface cordeau connection. The surface line does no work other than carry detonation.

Method of Making Surface Connection

The end of cordeau extending from the hole is split in half for about 3 inches in length and separated. A special tool called a ripper or slitter is used for this. A main or trunk line is laid along the top of holes on the surface so that the main line lies in the crotch formed by the split ends. These ends are twisted tightly around the main line, one to the right, the other to the left. A blast-



Method of wiring for a blast fired with Cordeau, using an electric blasting cap over each bore hole and no trunk line of Cordeau.



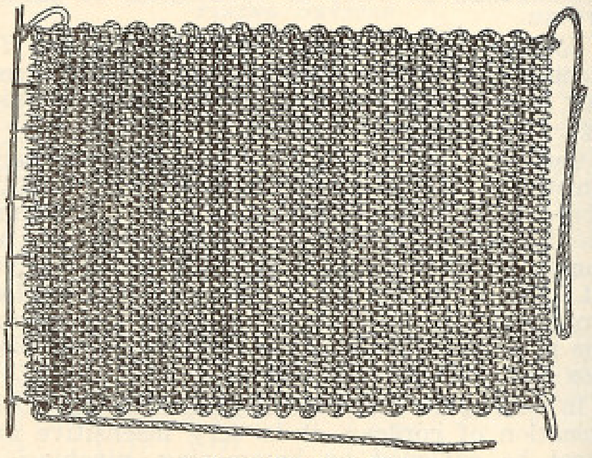
Showing trunk line of Cordeau and location of electric blasting cap.

ing cap or electric blasting cap is connected to the end of the main line and fired, detonating the whole blast. As many as 76 holes 86 feet deep have been fired with one blasting cap. Great care should be used to see that connections are tight and that the angle between the main line and branch line is a right angle. The explosive in the tube will not stand water and, in rainy weather, extreme care is necessary if surface connections are used.

The load of dynamite in well drill holes may be broken as many times as desired and still require only one line of cordeau. If the cordeau is broken while loading the explosives, no harm is done, but if it is broken while tamping, some dynamite should be loaded at that point and the tamping continued. The dynamite so loaded will assure the continuation of the detonation with no fear of a misfire.

Blasting Mats

Blasting mats are closely woven mats of hemp or wire rope. They are used over blasts or between blasts and property to catch or hold material flying from the blasts. Hemp rope is generally used and is considered the best, although steel wire rope has been tried with success. The mats are made of 1 inch, 1¼ inch or 1½ inch rope, according to the demands of the customer. They are not carried in stock, but are woven on order and are made in any size required. If the blasting mats are to cover light charges of explosives, they may be spread directly over the bore holes; but if heavier charges are used, railroad ties or logs should be put down



A Hemp Blasting Mat

first and the mats on top of them. Sometimes the mats are propped on lightly supported uprights several feet above the blast, so that when the blast is fired the flying rock is stopped by the under side of the mat.

These arrangements are very effective in preventing the rock from being thrown into the air and should always be adopted when blasting is done near thoroughfares or buildings. Boards and logs alone are not sufficient.

Thawing

Since many of the high explosives and many of the permissibles contain nitroglycerin, proper and safe methods of thawing are important. It is essential that the heat be moderate, because with increased temperature the explosive is more sensitive to slight shocks, and may even be fired by high temperature alone. Some crude methods, such as carrying in the clothing, placing near a fire or soaking in hot water may be dismissed as obviously unsafe from a consideration of the properties of nitroglycerin.

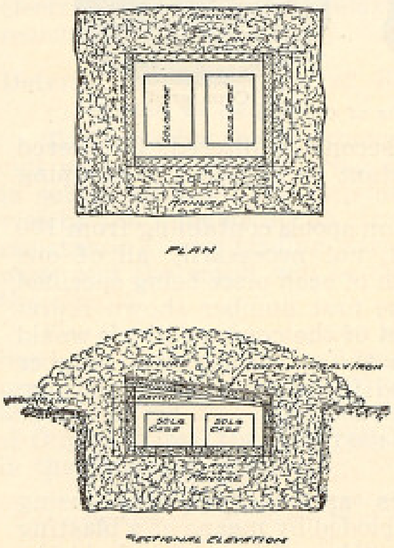


Fig. 26—Thawing Box Surrounded with Manure.

A simple method that is often practical is the placing of the explosive, enclosed in a tight box, under a pile of fresh and warm stable manure, Fig. 26. There is little danger, if any, of overheating, but care must be taken to prevent moisture from reaching the explosive, and the pile must be renewed at intervals, depending on the air temperature

A considerable improvement is the thawing kettle, which has a capacity of 60 pounds of dynamite for the largest size In external appearance, it resembles a tin pail, but is composed of two parts, an outer shell for hot water and a tight inner compartment, surrounded by the hot water and containing the explosive. Sometimes insulating material is used to assist in retaining the heat. One type is shown in Fig. 27. It is essential for safety that the heating of the water be completed in another vessel, before the water is placed in the kettle. The temperature should not be greater than can be borne by the hand. A modification of the kettle provides a galvanized iron tube for each cartridge to be thawed, as shown in Fig. 28, instead of placing the cartridges loosely in the inner compartment. By changing the water at intervals, or by protecting against cooling, the explosive may be kept at a temperature suitable for use as long as is generally necessary.

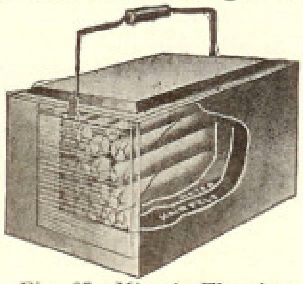


Fig. 27—Miner's Thawing Kettle.

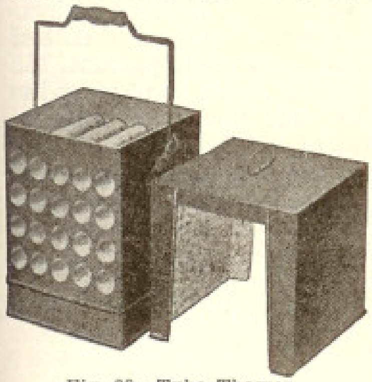


Fig. 28—Tube Thawer.

For thawing large quantities, a thaw house should be erected. An example of such a structure, about 6 feet square and 7 feet high, with capacity of 500 pounds of explosive, is shown in Fig. 29.

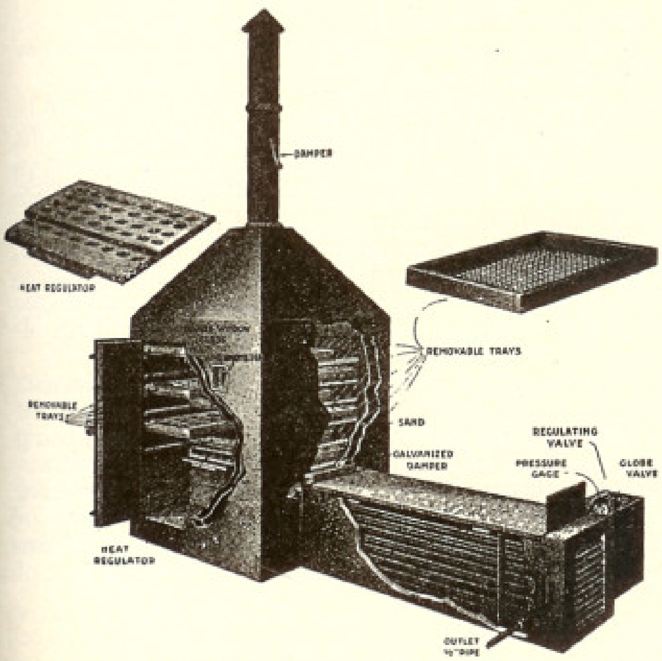


Fig. 29—Thawing House.

Exhaust steam is used for heat, and the steam coils are placed outside the compartment for explosives, in order to keep the temperature within safe limits. Hot water heat is sometimes used.

Storage

It is desirable to use explosives in as fresh a condition as possible, but at most mines the storage of a certain quantity is necessary, and for this purpose, magazines are provided. In no case should the storage space be in the mine. The important requirements are safety from ignition of the explosive and preservation of the explosive in condition for use.

Safety from ignition is attained chiefly by making magazines fireproof and bulletproof, as well as proof against thieves, by locating them at a distance from other buildings and frequented places, by using no metal in the interior of the magazine and by care in handling and piling the packages. Preservation of the explosive is accomplished chiefly by ventilation, protection from the weather and maintaining of proper temperature. In no case should detonators of any type be stored in the same magazine with high explosives, although it is considered safe to store black powder and high or permissible explosives in the same structure, if different parts are assigned for each. A standard type of magazine is shown in Fig. 30.

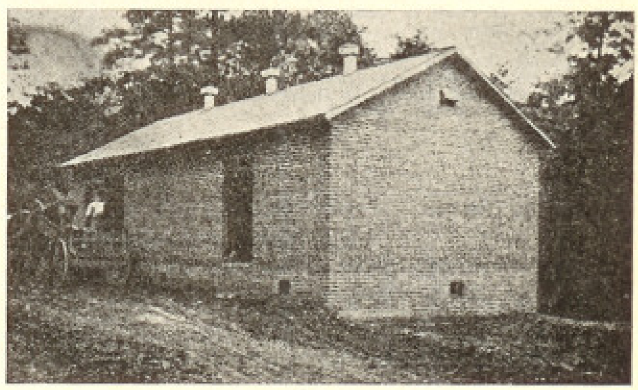


Fig. 30—Magazine.

Brick walls with iron doors are usually considered to make a fireproof structure, although a galvanized covering over wood is effective, particularly when the space between is filled with sand. Fireproof construction should not be depended on entirely, but provision should be made for removal of the contents in case of fire near the magazine. Either of the above is bulletproof on the sides, and roofs are made so with sand packing. The magazine should be solidly built and provided with a secure lock. The proper distance from other buildings depends on the quantity of explosive stored and the character of intervening ground, but laws bearing on this point aim to leave a safe margin. Floors and interior walls are of wood preferably, exposed nails or other iron or steel being avoided. In handling packages of explosives into and out of the magazine, the character of the explosive must be kept in mind; for example, dynamite must be handled so as to avoid dropping the cases, or allowing anything to drop upon the cases. Dynamite is preferably stored so that the cartridges have their long dimension horizontal, to reduce to a minimum the danger of nitroglycerin leakage. Powder kegs should be stored with the axis horizontal, in order to secure ventilation between the kegs. No packages should be opened in or near a magazine.

Ventilation is necessary in order to keep the explosive in normal condition. Too much moisture or too little moisture is likely to change the chemical composition of either class of explosives. Suitable openings in the sides and roof of the building serve the purpose of ventilation. High explosives magazines are heated in cold weather much as thaw houses are heated. In summer, the ventilation serves to reduce the inside temperature.

Portable steel buildings are sometimes used as magazines. Many of the precautions that should be taken are rendered difficult by this type of construction, but for a temporary magazine they serve their purpose. For storing small quantities close to the work, covered iron wagons or low trucks are sometimes used.

Accidents and Precautions

Fatal accidents due to explosives in the bituminous coal mines of the United States constitute about 5 per cent. to 7.5 per cent. of the total. Classification of accidents from this source is given in the following table:*

	Per Cent.
Handling and transportation	16.79
Handling caps, detonators, squibs and fuse	1.20
Thawing explosives	.73
Tamping	2.97
Premature blast and short fuse	24.87
Blown-out or windy shot	5.47
Flying pieces of rock or coal	16.71
Returned too soon	7.97
Delayed blast	.90
Shot breaking through pillar or rib	5.88
Suffocation by powder gas	3.45
Striking unexploded charge in removing debris	.08
Drilling into unexploded charge	1.88
Unclassified	11.10
	100.00

It is significant that a decrease in accidents accompanies an increase in the quantity of permissibles used.

Many of the precautions necessary or advisable in the transportation, handling and use of explosives have been mentioned in the pages preceding, and will not be repeated here.

Transportation on the common carriers is controlled by the regulations of the Interstate Commerce Commission and the rules of the American Railway Association. State and local laws govern the transportation elsewhere on surface and underground.

The mining laws of the several states treat in more or less detail the handling and use of the explosives adapted to mining, and are valuable summaries of safe practice in the fields covered by them.

All manufacturers of explosives are interested in having their products used safely, as well as successfully, and to this end have prepared lists of precautions for the guidance of their patrons. In addition, the Institute of Makers of Explosives has published a set of rules that should be observed faithfully in the interest of safety.

If proper precautions are taken, such as would be dictated by ordinary prudence and suggested by the codes of rules named above, the handling of explosives is comparatively safe.

*"Coal Mine Fatalities in the United States," Bureau of Mines.

NOTE—We are indebted to the following manufacturers for cuts and illustrations appearing in this article:

Aetna Explosives Co., Inc. — Davis Instrument Mfg. Co.
Atlas Powder Co., — E. I. du Pont de Nemours & Company,
Hercules Powder Co.

THEORY OF BLASTING*

Conditions Influencing Results of Blasting

Size and number of free faces; cohesive strength of the rock; structure of rock (massive, jointed, laminated, stratified, or fissured); strength and nature of the explosive; character of fuse and tamping; whether the shot acts alone or simultaneously with others; whether the broken rock falls or must be lifted by the blast; form and size of chamber containing the explosive; proportion of length of least resistance to length of the hole, and to height of free faces.

Rules for Blasting

According to the crater theory, a charge in a mass of earth or rock with horizontal surface will blow out a funnel-shaped hole, the sides of which have a slope of 1 to 1 to the free face (Fig. 5). Distance DB is the Line of Least Resistance L; hence the volume of the crater is $V = 0.33\ L \times 3.1416\ L^2 = L^3$ (nearly). Hence general formula for volume of rock loosened is $V = mL^3$. The figure from m = 0.4 for tough soft rock, and 0.9 for hard brittle rock.

If the hole is normal, as in Fig. 5, the charge may blow out tamping and fail to break; hence, hole should be inclined (Fig. 6), to reduce chances of a blow-out, as well as to increase the area of free face and volume of the rock broken. Limiting inclination of drill hole is 45°.

The greater the area of free face, the easier can rock be blasted. Fig. 7 shows the area of volume broken when there are two free faces (point G being uncertain) Fig. 8 shows area when charge is at unequal distances from the two faces; shaded area will probably not be removed by the direct force of the blast, but may be broken indirectly. When two or more free faces are exposed, the longest line of

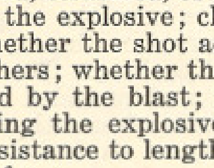


Fig. 5. Theoretical Crater, Normal Hole.

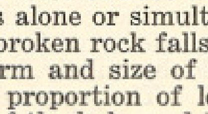


Fig. 6. Theoretical Crater, Oblique Hole.

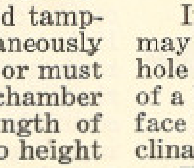


Fig. 7. Hole With Two Free Faces.

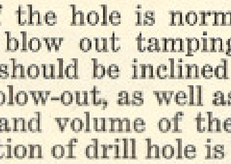


Fig. 8. Hole With Two Free Faces.

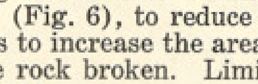


Fig. 9. Effect of Holes Fired Simultaneously.

*Peele's Mining Engineers' Hand Book.

ATLAS POWDER CO.

WILMINGTON, DELAWARE

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EXPLOSIVES AND BLASTING POWDERS

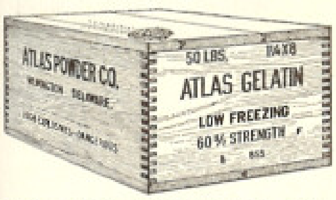
The high quality, uniformity and dependability of Atlas Explosives are recognized by all powder men connected with great metal mines. All grades for every requirement can be furnished conveniently by the nearest of our many distributing points. All Atlas Explosives are low-freezing or non-freezing. Nothing weaker than a No. 6 blasting cap should be used to detonate Atlas Explosives.

Cartridge—Atlas L. F. Extra 40%

Atlas Ammite—A new explosive that will not freeze. The ideal explosive for all-year-round work. Made in 6 grades, covering all blasting requirements.

Atlas Dynamite—25% to 60%. Very quick and shattering. Fumes of grades lower than 50% not objectionable underground. Partly waterproof. Recommended for outside work in hard rock that must be broken small.

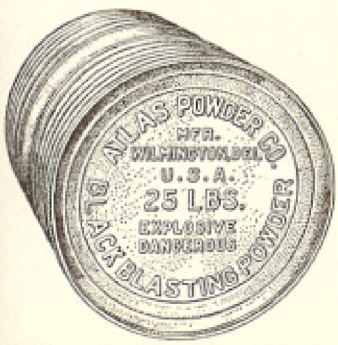
Atlas Extra—15% to 60%. Spreads and heaves when detonated. Fumes not objectionable. Not absolutely waterproof. Especially recommended for quarries, strippings, cuts and underground blasting that is not very wet and where a highly shattering effect is not desired.



Case—Atlas Gelatin L. F. 60%

Atlas Gelatin — 25% to 80%. Practically non - freezing. Fumeless excepting the 80%. Waterproof. For tunnel driving and rock blasting of all kinds in mines or under water.

Atlas Permissible—COALITE. Ten grades to meet every coal mining requirement. No objectionable fumes. Cold resisting. All grades have been tested and approved by the U. S. Government Bureau of Mines.



Keg—Atlas Blasting Powder

Atlas Low Freezing R. R. P.—Granular, low grade explosive, invaluable in cuts, strippings or other open excavating where the work is not wet. Twice as strong as blasting powder. Exploded with dynamite primer. Put up in 12½ lb. paper bags; packed in 50 lb. cases.

Atlas Blasting Powder—All standard granulations. The smaller the grains, the quicker and more shattering the effect. Little smoke. Hard pressed, dense, regular, moisture resisting grains. Glazed. Packed in 25-lb. kegs and 5-lb. cans.

BLASTING SUPPLIES

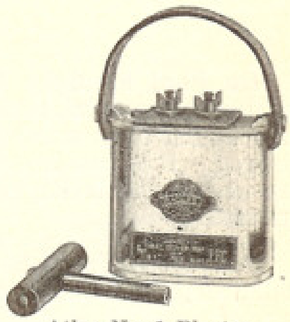
Atlas Blasting Caps—No. 6 and No. 8. Detonated by fuse. Packed 25 to 100 to the tin box, 500 or 5,000 to the case.

Blasting Caps—Atlas Electric No. 8

Atlas Electric Blasting Caps—No. 6 and No. 8. Copper or iron wires. Detonated by electric blasting machine. Packed 25 and 50 to the carton—10 cartons to the case. Wires 4 ft. to 30 ft. long. Longer lengths supplied on request.

Atlas Blasting Machines—Six sizes ranging in weight from 3¾ lbs. to 53 lbs., and in capacity from 1 to 150 electric blasting caps.

Three sizes particularly suited for blasting where not more than 1, 5, or 10 shots are fired together. Dimensions: Smallest size 4¾"x2"x4½" high.



Atlas No. 1 Blaster

Fuse — Nine different brands for carrying spark to blasting caps or blasting powder under all conditions. Wrapped in rolls of 100 feet. Packed 5 to 60 rolls to the case.

Atlas Cap Crimpers—For attaching blasting caps to fuse in a safe, secure and reliable way—No. 4, Indented Crimp; No. 5 Broad Jaw Crimp; California Broad Crimp.

Connecting Wire—Small, insulated copper wire for connecting electric blasting caps to each other. 1-lb. and 2-lb. spools. About 230 ft. to the lb. for No. 20 wire; about 290 ft. to the lb. for No. 21 wire. Sold by the lb.

Leading Wire—Heavily insulated copper wire, used to carry the current from blasting machine to the charge. Single leading wire runs about 49 feet to the lb; duplex, about 26 feet to the lb. Sold by the lb.

Atlas Galvanometers—For testing electric blasting circuits. This instrument is enclosed in a leather carrying case, with a sling strap.

Atlas Rheostats—For testing the capacity of blasting machines. Dimensions: ¾" x 1¾" x 5½". Weight: 5½ oz.

Atlas Moisture Proof Blasting Cap Carrying Case—The first device of its kind offered the miner that enables him to take proper care of a day's supply of blasting caps. Made of aluminum ⅞"x2⅛"; holds seven No. 6 or No. 8 blasting caps.

Atlas Moisture Proof Blasting Cap Carrying Case

Other Atlas Blasting Supplies include Sureshot Shells Tamping Bags, Thawing Kettles, Delay Electric Blasting Caps, Delay Electric Igniters, Cordeau-Bickford, Blasting Paper, Kapseal, Portable Magazines, Electric Squibs, Miners' Squibs, etc.

Other Atlas Products include Chemicals, Nitro Cellulose Solutions, Leather Cloth, Lacquers, Enamels, Pyroxylin Cements.

E. I. du Pont de Nemours & Company, Inc.

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Locations of Explosives Plants and Blasting Accessories Factory:

High Explosives: Ashburn, Mo.; Barksdale, Wis.; Du Pont, Wash.; Louviers, Colo.; Ramsay, Mont.; Gibbstown, N. J.
Blasting Powder: Augusta, Colo.; Connable, Ala.; Du Pont, Wash.; Nemours, W. Va.; Fairchance, Pa.; Jermyn, Pa.; Laurel Run, Pa.; Mooar, Iowa; Moosic, Pa.; Oliver Mills, Pa.; Peckville, Pa.; Wapwallopen, Pa.; Wilpin, Minn.
Blasting Accessories: Pompton Lakes, N. J.

High Explosives, Blasting Powder and Blasting Accessories

In the course of more than a century's experience in the manufacture and sale of explosives, the du Pont Company has acquired a very extensive practical knowledge of the qualities needed in explosives for various purposes and the most efficient methods of using them. Du Pont explosives include types for all classes of blasting, all made from carefully selected materials with a care in manufacture which insures the highest quality and uniformity.

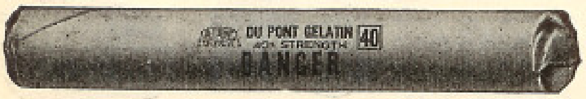
The following paragraphs state briefly the chief characteristics of du Pont explosives adapted for metal mining and quarrying, and describe the accessories needed for firing them. For more complete information as to the selection of the proper explosives and the methods of using them to secure the greatest execution at the lowest cost of accessories, time and labor, consult the catalogs and booklets issued by this Company.

EXPLOSIVES FOR MINING

Du Pont Straight 15-60%. This explosive is quick and powerful, resists water well and is recommended for open work where a shattering action is desired. It is low-freezing and is suitable for mining where ventilation is exceptionally good, and for quarrying.

Red Cross Extra 20-60%. This is an all-year-round explosive that works extremely well in mining soft ore. It is also suitable for hard ore where it is not desired to shatter the material. Red Cross Extra is low-freezing.

Du Pont Gelatin 25-90%. Where other explosives are inefficient this gelatin does its best work. It is adapted to a wider range of work than any other gelatin dynamite for it has all the virtues of density, plasticity, water resistance, and comparative freedom from obnoxious fumes, and is low-freezing. It is especially adapted for close work of every kind, mining and tunneling in the hardest rock under the most adverse conditions.



Repauno Gelatin 25-90%. This is a dense, plastic, highly water-resisting, and low-freezing explosive which gives a minimum of fumes on explosion. It is particularly suitable for wet work or where ventilation is deficient.

Du Pont Blasting Gelatin 100%. This is the strongest and quickest high explosive manufactured. It can be used in close work as it gives a minimum of fumes when exploded. It is practically waterproof but is not low-freezing. It is especially suitable for blasting hard material in tunnels or in driving shafts.

Packages: Du Pont high explosives cartridges measure from 7/8" by 8" to 2" x 8". They are shipped in cases which contain from 33 to 225 cartridges to the 50-pound case.

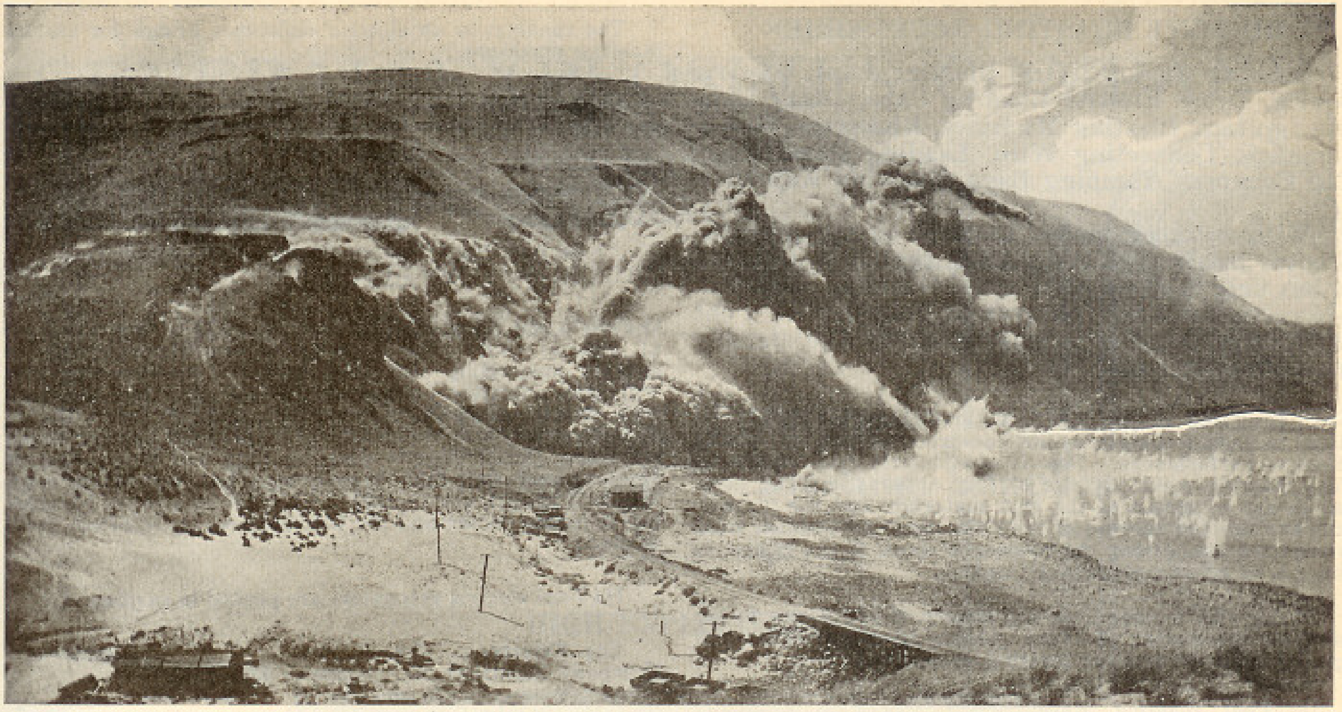
Blasting Powder

Blasting Powder is the principal explosive used for blasting where it is necessary to remove the rock or earth covering ore veins. The blasting powder breaks and loosens the ore, earth and rock so that it can readily be loaded with steam shovels. It is not wasted or scattered as would be the case if high explosives were used.

Today the "B" Blasting Powder of the du Pont Company is recognized as the standard by which other blasting powder is rated. The high quality of materials used and their thorough incorporation by means of special machinery give the miner a reliable, efficient explosive. That the miners recognize this is shown by the increasing demand.

"B" Powder is made in seven granulations. This variation in the size of the grains enables the selection of a grain exactly suited to individual requirements. The finer grains are much quicker in their action than the coarser.

Packages: Blasting Powder is packed in 25-pound metal kegs having a moisture proof cap.



Blast of 17,231 Kegs of du Pont Blasting Powder and 13,658 Pounds of du Pont Red Cross Extra Dynamite in 68 Small Tunnels on O. W. & N. R. R. at Ayer, Washington. 300,000 Cubic Yards of Earth and Rock Blasted

EXPLOSIVES FOR QUARRYING

Red Cross Extra 20-60%. This explosive will rarely freeze in the coldest weather and is fairly water resisting. It will not shatter the rock when properly loaded.

Dumorite. Dumorite is a guncotton nitroglycerin dynamite which ordinarily will do the work of regular 40% dynamite. As it is a low density powder, running from 135 to 140 cartridges, 1¼"x8", to the 50-pound case, and is loaded on a stick basis against 40% dynamite, it is fully one-third cheaper. Dumorite resists water about as well as Red Cross Extra and is absolutely non-freezing. It will not cause headache.

Quarry Gelatin 25% to 75%. This is a high explosive recently developed combining the high density, water resisting and low freezing properties of du Pont Gelatin. It is adapted only for open work and must not be used in mines, tunnels or other close work. It has considerably more shattering power than corresponding grades of du Pont Gelatin, especially noticeable in the 25% and 30% strengths.

Du Pont, Repauno and Forcite Gelatin 25-90%. These are moderately slow, low-freezing and water resisting explosives. Du Pont Gelatin is perhaps adapted to a wider range of work than any similar explosive. For quarrying hard rock in wet places any one of the three can be used.

Durox. This is an explosive of relatively high strength yet low density which is especially adapted for blasting rock where a shattering effect is not desired. It is low-freezing.

Du Pont Blasting Gelatin 100%. For a quick, shattering explosive this will serve best. It is not low-freezing but is not affected by water.

Du Pont Straight 15-60%. Recommended for open work, in wet, hard material. It is low-freezing.

Du Pont Quarry Straight 15% to 60%. This is another new high explosive developed for open work only. It is similar to du Pont Straight in every respect except that it is somewhat more shattering, especially in the lower grades.

Du Pont Extra 20-60%. This is better suited for blasting soft material than straight dynamite but does not resist water well. It is low-freezing.

Du Pont R. R. P. This is the weakest and slowest high explosive—ranking between blasting powder and dynamite. It will rarely freeze but even when frozen will explode properly if the lumps are crumbled.

Blasting Powder

Blasting powders are weaker and slower than high explosives, exerting a lifting and heaving, rather than a shattering effect. "A" powder is made in six granulations and "B" in seven. The fine granulations are quicker than the coarser. Blasting Powder cannot be used in wet work although "A" resists moisture better than "B". Neither is affected by cold.

EXPLOSIVES TO MEET VARIOUS QUARRYING CONDITIONS

	STRAIGHT	RED CROSS EXTRA	DU PONT EXTRA	GELATIN	DUMORITE	DUROX	BLASTING POWDER	R. R. P.
To shatter and throw hard stone	X			X				
To shatter and throw medium hard stone	Lower strength			X				
To turn out hard, tough stone		X 40 to 60%	40 to 60%	X				
To turn out medium hard stone		Lower strength	Lower strength	X	X	X		X
To turn out soft or dimension stone...						X	With air spaces	With air spaces
For wet work.......				X				
In cold weather.....	X	X		Except Blasting Gelatin	X		X	X
To avoid shattering.					X	X	X	X

Packages—All except R.R.P. (in bags) and Blasting Powder (25 lb. keg) are packed in 25 and 50 lb. cases.

DU PONT BLASTING ACCESSORIES

Blasting Caps, Electric Blasting Caps, Electric Squibs, Delay Electric Blasting Caps, Delay Electric Igniters, Blasting Machines, Rheostats, Galvanometers, Connecting Wire, Leading Wire, Fuse, Cap Crimpers, Tamping Bags, Thawing Kettles.

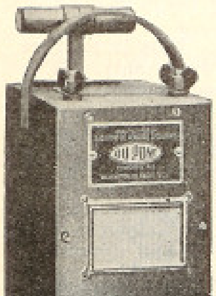
With so much money involved in the preparation for blasting, it is apparent that it is economy to buy only the best blasting accessories. The confidence miners and quarrymen have in du Pont blasting accessories is manifested by the steadily increasing demand.

In designing the du Pont accessories, care has been exercised to obtain simplicity of construction and to ensure effective performance. This is particularly true of the du Pont blasting machines and testing apparatus. The detonators are composed of the best materials and the ingredients are selected because of their fitness to accomplish what is required—imparting the necessary shock to the explosive charges to effect complete detonation.

If you wish to save time and money, if you desire to get complete detonation of every charge of explosives, insist upon the use of du Pont blasting accessories.

Du Pont Blasting Machines—The du Pont Company makes several sizes of blasting machines having capacities of 1 to 150 electric blasting caps fitted with copper wires. The most popular sizes are the Pocket Blasting Machine and Nos. 3 and 4.

The No. 3 Blasting Machine is illustrated below. The Pocket Blasting Machine also is shown on this page.

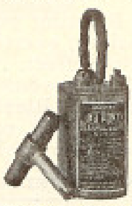


Blasting Machine

Blasting Machines Nos. 3 and 4 fire 30 to 50 copper wire electric blasting caps. They weigh 25 and 42 pounds, respectively. The machines are compact, as shown in the illustration, easy to operate and portable. The No. 3 Blasting Machine is the standard size for quarry and mine. No. 4 is popular for large quarry blasts.

Blasting Machine No. 3-A is a new machine of modern construction, light weight and high capacity. It is rated to fire 50 electric blasting caps with a considerable margin of safety.

The Pocket Size fires from one to three electric blasting caps at a time. It has a removable handle to prevent anybody but the shot-firer from firing the charges — a "safety - first" device greatly appreciated by quarrymen and miners. A quick, sharp turn of the handle generates the current which passes through the two terminals seen at the top of the case, and then through leading wires attached to the terminal posts.



Pocket Blasting Machine

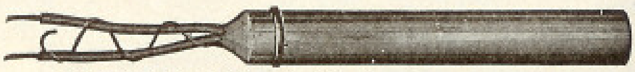
So much depends on the blasting machine, that the safest thing to do is to purchase the best.

Galvanometers, Rheostats — Practically indispensable accessories in electric blasting in mine or quarry are the galvanometer and the rheostat illustrated on this page. The galvanometer is a small, direct-reading ohmmeter used to detect breaks, short circuits, and points of high resistance in blasting circuits.

Galvanometer

The rheostat is an electric resistance bridge for testing blasting machines.

Electric Detonators. After careful experiments extending over many years, the du Pont Company has developed



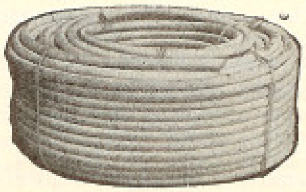
Du Pont No. 8 Electric Blasting Cap—Exact Size

the No. 6 and No. 8 Electric Blasting Caps as best fitted for all general work. The selection of the materials and the care in assembling the parts assure a blasting cap that will give complete detonation. These caps are furnished with wires in lengths varying from 4 to 20 feet. The du Pont Company also manufactures Waterproof Electric Blasting Caps, Delay Electric Blasting Caps and Delay Electric Igniters, and furnishes leading wire and connecting wire. The best results are secured from blasting powder by igniting it in the center and for this purpose the Electric Squib is made.

Du Pont electric detonators are packed in cartons of 50

Cap Crimpers. The du Pont Company furnishes cap crimpers of two types, No. 1 and No. 2. The No. 2 Cap Crimper is also used for cutting fuse. One handle is pointed to serve as a punch for making holes in cartridges.

Cap Crimper



Safety Fuse. Safety fuse for use with blasting caps is also sold by the du Pont Company, different types being manufactured for dry, damp or wet work, or work under water. It is made in coils of 50 feet and shipped in wooden cases.

DU PONT EXPLOSIVES SERVICE

For 122 years it has been the constant aim of the du Pont Company to deliver explosives where they are needed—when they are needed. Today this aim has been achieved by a system of mills and magazines, strategically located near practically every great industrial district.

Prompt delivery is but one factor of du Pont Service. We aim to see that our customers use the kind of explosives that will give the best results for their particular work at least expense—and that they are handled, stored and used most efficiently.

In short, du Pont Service is the result of a sincere effort on the part of the du Pont Company to meet and follow the demand, and to pass on to the users of their products, in a practical way, the results of their 122 years of experience and research in the manufacture of explosives.

When you buy from du Pont, you buy more than explosives; you buy du Pont Service.

E. I. DU PONT DE NEMOURS & CO., INC.
Explosives Department
WILMINGTON, DELAWARE

GENERAL EXPLOSIVES COMPANY

7 South Dearborn Street
CHICAGO

ST. LOUIS, MO. DENVER, COLO. JOPLIN, MO.
BIRMINGHAM, ALA. TAMPA, FLA.

High Explosives — Permissible Explosives
Blasting Powders — Blasting Supplies

HIGH EXPLOSIVES

GENERAL NITROGLYCERIN DYNAMITE is the old reliable "Nitro" powder compounded on scientific principles so as to produce the maximum results. It is very quick and shattering in action and is used for mud capping and for blasting extremely hard rock.

Made in both high and low freezing grades and in strengths ranging from 15% to 60%. A 50-lb. case contains about 100 1¼x8″ cartridges.

GENERAL SPECIAL (Ammonia) DYNAMITE is a very economical powder for many kinds of mining and quarry work both above and below ground except where extreme shattering is required. It produces but little fumes and can be used wherever moderately good ventilation exists. Made in both high and low freezing grades. Most mines prefer to use the low freezing grade in winter and some use it the year round. Made in strengths from 20% to 60%. A 50-lb. case contains about 100 1¼x8″ cartridges.

GENERAL GELATIN is without any question the most satisfactory explosive on the market for underground work. Its plastic consistency, which facilitates loading in uppers, and its freedom from fumes, have made it invariably the favorite wherever used. Long experience in the powder business combined with expert technical knowledge of the requirements has enabled us to accomplish these results.

It withstands water better than any other form of explosive and is made in both high anu low freezing grades in strengths from 25% to 90%. A 50-lb. case contains about 85 to 90 1¼x8″ or 103 to 108 1⅛x8″ cartridges.

THE GIANT POWDER CO., CON.

First National Bank Bldg., SAN FRANCISCO, CAL.

BRANCH OFFICES
Butte, Montana
Denver, Colorado
Los Angeles, California

BRANCH OFFICES
Portland, Oregon
Salt Lake City, Utah
Seattle, Washington
Spokane, Washington

"Everything for Blasting"

EXPLOSIVES AND BLASTING POWDER

Giant Explosives

Made by the pioneer company in the explosive industry, Giant Explosives are still the most popular in the West, because their qualities are recognized as superior in meeting western requirements. Nothing weaker than a No. 6 blasting cap should be used with Giant Explosives.

Giant Ammite

An explosive furnished in six grades. Cannot freeze. An explosive that is ideal for all-year-round use.

Giant Dynamite—25% to 60%
For open work where shattering is demanded.

Giant Extra—15% to 60%
For all rock and ore blasting not exceptionally wet.

Giant Gelatin—25% to 80%

For rock blasting, tunnel driving and all wet work. Waterproof. Grades under 80% fumeless.

Giant Coalite

A permissible explosive furnished in ten grades to meet every coal mining requirement, tested and approved by U. S. Bureau of Mines. Cold resisting—one grade non-freezing. No objectionable fumes.

Giant Judson Improved Powder—5%

For open excavation blasts that are not wet. A granular, low powder, twice as strong as blasting powder. Put up in 12½ lb. bags; packed in 50 lb. cases. 10%, 15% and 20% not granular and put up in cartridges.

Giant Blasting Powder

For all dry work where a quick acting explosive is not required. All standard granulations. Glazed.

Case—Giant Extra L.F. 60%

Keg—Giant Blasting Powder

Case—Giant Gelatin V.L.F. 40%

BLASTING SUPPLIES

Giant Blasting Caps—No. 6 and No. 8. For blasting with fuse.

Giant Blasting Cap Carrying Case (Moisture proof). Carries and protects seven No. 6 or No. 8 blasting caps. The only safe and convenient means for the miner to carry his day's supply of blasting caps.

Giant Electric Blasting Caps—No. 6 and No. 8. Copper or Iron wires. For blasting with electric blasting machines.

Giant Blasting Machines—Six sizes, including the two sizes of Giant Blasters, which are small and light weight machines that fire 5 or 10 electric blasting caps. Other sizes have capacity of from 50 to 150 electric blasting caps.

Fuse—For detonating blasting caps or exploding blasting powder.

Giant Cap Crimper—For attaching blasting caps safely and securely to fuse.

Giant Cap Carrying Case

Connecting Wire—For connecting electric blasting caps to each other. Small, insulated copper wire wound on spools containing 1 and 2 lbs.

Leading Wire—For carrying electric current from blasting machine to charge. Heavily insulated copper wire.

Giant Galvanometer — For testing electric blasting circuits. Dimensions — 1¾"x3½"x4½". Weight—1½ lbs.

Giant Rheostat—For testing capacity of electric blasting machines. Dimensions: ¾"x1¾"x5½". Weight, 5½ oz.

Other Giant Blasting Supplies—Include Delay Electric Blasting Caps, Delay Electric Igniters, Electric Squibs, Magazines (Portable and Storage), Sureshot Shells, Cordeau Bickford, Blasting Paper, Celakap, Tamping Bags, Thawing Kettles, etc.

Giant Electric Blasting Cap No. 8

Giant Blasting Machine No. 6

THE GRASSELLI POWDER COMPANY

CLEVELAND, OHIO

ESTABLISHED 1839
CHEMICALS
ZINC
GRASSELLI
EXPLOSIVES
DYESTUFFS

PITTSBURGH, PA.
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HAZLETON, PA.
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CHICAGO, ILL.
PHILADELPHIA, PA.
POTTSVILLE, PA.
WILKES-BARRE, PA.

For every blasting job there is a Graselli explosive exactly fitted for that job. We here list briefly the general characteristics of our various grades, and shall be glad to have one of our practical service men call and explain them to you in detail. He will also, if you desire, go over your blasting proposition with you and assist in selecting the grade best suited to conditions in your operation.

Nitro Glycerin Grade

Made in strengths from 20% to 60%.

A powerful, hard-hitting explosive for shooting hard, tough material. Can be shot successfully in wet holes and is ideal for mudcapping.

Made in low-freezing and straight grades. 1¼ x 8 inch cartridges pack 100 to the 50-pound case; other sizes in proportion.

Gelatin Grade

Made in strengths from 25% to 75%.

The ideal explosive for wet work and where ventilation is not good. It is free from objectionable fumes and particularly adapted to tunnel work, shaft sinking, etc. Its plasticity enables it to be effectively loaded in upward-slanting or even in vertical overhead holes.

Made in low-freezing and straight grades. Averages 88 1¼ x 8 inch sticks per 50 pound box; other sizes in proportion.

Ammonia Grade

Made in strengths from 20% to 60%.

A general, all-around explosive. Its action is not as quick or shattering as the above grades, producing more of a lifting and heaving action, and therefore more desirable for many classes of work.

Made in low-freezing and straight grades. Averages 106—1¼x8 inch sticks per 50-pound case: other sizes in proportion.

Special Grades

We also manufacture special grades to meet certain special conditions. They vary as to speed, expansion, etc., according to the requirements of the job for which they are to be used.

Blasting Powder

Made in various granulations from CCC which is of slow, heaving action, to FFFF, for shooting material requiring a sharp, quick and more shattering action.

Uniform granulation, hard pressed and well glazed.

Blasting Supplies

Blasting Caps.

Electric Blasting Caps—Copper or Iron Wires—Various Lengths.

Safety Fuse—All Grades.

Cordeau-Bickford—The Detonating Fuse.

Cordeau Accessories.

Blasting Machines—For Firing Electric Blasting Caps—Capacities 1 to 150 holes.

Rheostats—For Measuring Strength of Blasting Machines.

Galvanometers—For Testing Blasting Circuits.

Cables, Lead and Connecting Wire, etc.

HERCULES POWDER CO.

WILMINGTON, DELAWARE

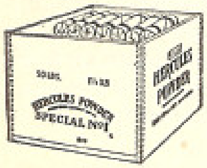
BRANCH OFFICES

Allentown, Pa.
Birmingham, Ala.
Buffalo N. Y.
Chattanooga, Tenn.
Chicago, Ill.
Denver, Colo.
Duluth, Minn.
Hazleton, Pa.
Huntington, W. Va.
Joplin, Mo.
Los Angeles, Cal.
Louisville, Ky.
New York City
Norristown, Pa.
Pittsburg, Kan.
Pittsburgh, Penna.
Pottsville, Penna.
St. Louis, Mo.
Salt Lake City, Utah
San Francisco, Cal.
Wilkes-Barre, Pa.

Explosives, Blasting Supplies and Flotation Oils

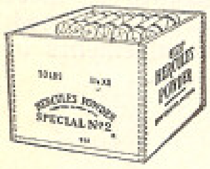
Hercules Special No. 1

Because of its high cartridge count and low cost per cartridge, Hercules Special No. 1 is more economical on work for which it is suited than ordinary dynamite. There are about 1/3 more cartridges of Special No. 1 in a box than there are of ordinary dynamite in the same size cartridges. Hercules Special No. 1 frequently replaces 40% dynamite, cartridge for cartridge, at a saving of approximately 25 per cent. Special No. 1 is a "bulky" explosive, hence not as good as gelatin where a concentrated charge is desired, as in tunnel driving in hard tight rock; however, for quarrying, open pit mining, road building, and some underground work it is both effective and economical.



Hercules Special No. 2

Hercules Special No. 2 is similar to Special No. 1, but is not quite as strong. Special No. 2 is usually more economical for blasting gypsum, clay, shale and some of the easier-breaking rock formations. It is also well suited for nearly all agricultural blasting. It has the same high cartridge count as Special No. 1 but costs less per pound and per cartridge. On work for which it is suited, no high explosive on the market is more economical than Hercules Special No. 2.

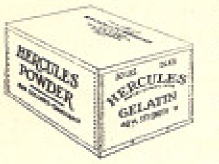


Hercules Gelatin Dynamite

Hercules Low Freezing Gelatin Dynamite is distinguished by plasticity, high density, imperviousness to water, and freedom from noxious fumes. It is made in strengths from 25% to 75%.

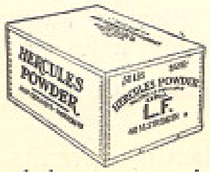
Hercules Gelatin is good for wet work, or for use where ventilation is poor. Its plasticity enables it to be loaded easily and effectively in holes having an upward slant, and the density and plasticity make it extremely well adapted for tight blasting in hard rock, such as tunnel driving, shaft sinking, etc.

Packed in standard cartridges, 50 lbs. to the case.



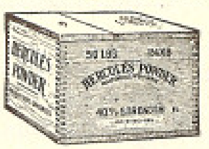
Extra (Ammonia) Dynamite

Hercules Low Freezing Extra Ammonia Dynamite is made in strengths from 15% to 60%. It is less expensive than the Gelatin or Straight Nitroglycerin Dynamites and is recommended for mining, quarrying, digging wells, road and railroad construction, clay blasting and mud capping. It is not as waterproof as Gelatin or Straight Nitroglycerin Dynamites, but this defect is largely overcome by double dipping in paraffine. Packed in standard cartridges, 50 lbs. to a case.



Straight Nitroglycerin Dynamite

Hercules Low Freezing Nitroglycerin Dynamite is manufactured in strengths from 15% to 60%. It is suitable for work where a strong and quick explosive is required, and is, therefore, recommended for all kinds of hard, tight work where finely broken material is desired, and where the ventilation is good. It is also adapted for mudcapping, scrapping boilers and castings, propagated ditch and canal excavation. Packed in standard cartridges, 50 lbs. to the case.



Blasting Gelatin

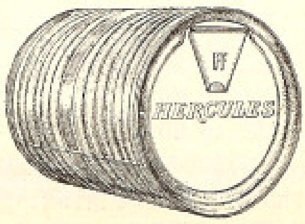
Blasting Gelatin is the strongest, quickest and most waterproof explosive manufactured for commercial purposes, having a strength of 100%. Hercules Blasting Gelatin is especially adapted for use in cut holes, hard rock tunnel rounds, loads at the bottom of deep well-drill holes, submarine blasts in hard rock, and as a primer for gelatin under special conditions. Packed in standard cartridges, 50 lbs. to the case.

R. R. P.

Hercules R. R. P. belongs to the class of explosives known as granular dynamite, often called Judson. It is best adapted for use in soft seamy material and for large tunnel or "coyote hole" blasts in hard rock. Packed in paraffine paper bags containing 12½ lbs. The standard case holds four of these bags, making a net weight of 50 lbs.

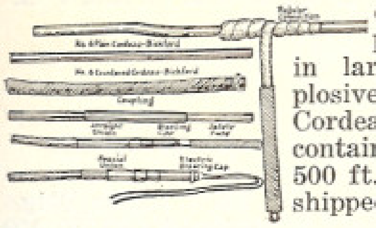
Hercules Blasting Powder

Hercules Blasting Powder is manufactured in all sizes of grains, glazed and unglazed, from FFFF, about 1/16 inch diameter, to CCC, about 1 inch diameter. A special powder called "Herco" is made for Hercoblasting, a new method of blasting with black powder in column loads in well-drill holes.

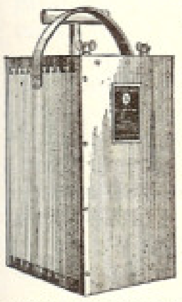


Packed in kegs containing 25 lbs.

Cordeau-Bickford Detonating Fuse



Cordeau is a fuse that detonates throughout its entire length, and is particularly effective in large charges of explosives. It is waterproof. Cordeau is wound on spools containing from 200 ft. to 500 ft. each and it may be shipped by express.



Hercules Blasting Machines

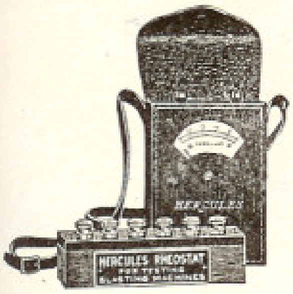
An apparatus for generating electric current used in firing electric blasting caps, squibs, and igniters; made in three sizes:

Midget—Pocket Size. 5 Electric Blasting Caps
Hercules No. 2 ...... 10 Electric Blasting Caps
Hercules. .... 50 Electric Blasting Caps

Galvanometers

A reliable and compact instrument for testing electric blasting circuits, electric blasting caps, and for locating breaks, short circuits, faulty connections. Weight 1 pound.

Hercules Rheostats



A small instrument offering the easiest and most effective means of testing the strength of a blasting machine without actually firing a series of electric blasting caps. This instrument gives a resistance equal to from 5 to 100 electric blasting caps, with 30 ft. copper wires.

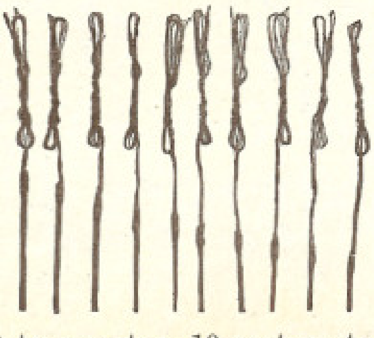
Electric Blasting Caps

These are used to detonate charges of high explosives by means of electricity. They are made in two strengths, No. 6 and No. 8. These are furnished with insulated copper wires from 4 to 30 ft., or with iron wires from 4 to 8 ft. Packed 25 or 50 to the carton, 10 cartons to the case.

Electric Squibs

Hercules Electric Squibs are similar in appearance to Electric Blasting Caps, and are used to fire charges of blasting powder. Electric Squibs are made with 4 to 8 ft. iron wires, and 4 to 30 ft. copper wires. Packed 25 and 50 to the carton, 10 cartons to the case.

Delay Action Electric Exploders

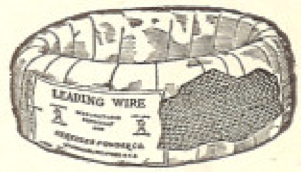


A combination Electric Igniter, Fuse and Blasting Cap, properly waterproofed, designed to fire charges in rotation by electricity, made in ten different delay periods. Furnished with copper wires, length 4 to 20 ft. Packed 25 and 50 to a carton, 10 cartons to the case.

Delay Electric Igniters

These igniters are similar to delay action exploders, made in six delays and used for firing charges of black powder in rotation. If desired, blasting caps may be crimped on the end of the igniter and used to fire high explosives. Furnished with copper wires 4 to 20 ft. Packed 50 to a carton, 10 cartons to the case.

Leading Wire

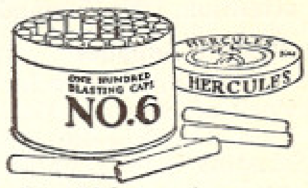


Hercules Leading Wire is an insulated copper wire (No. 14 B. & S. gauge) used for connecting electric blasting caps to the blasting machine. It is furnished in coils from 200 ft. to 500 ft.

Connecting Wire

Hercules Connecting Wire is used to join the wires of electric blasting caps. It is a high grade insulated copper wire (No. 20 B. & S. gauge), and is put up in one and two pound spools.

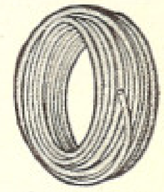
Blasting Caps



Blasting Caps are used to detonate charges of high explosives. As the efficiency of any high explosive depends on the initial detonation, we do not recommend caps smaller than Hercules No. 6.

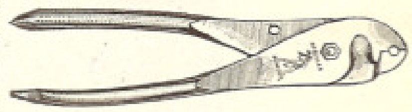
Standard sizes Nos. 6 and 8. Packed 100 in a box, 5 to 50 boxes in a case.

Safety Fuse



We are not manufacturers of safety fuse. We purchase and sell the various standard brands of safety fuse as manufactured in this country. The manufacturers of safety fuse give an estimated burning speed for every brand. Fuse is packed in coils of 100 feet. Cases contain from 5 to 60 coils.

Cap Crimpers



Hercules Combined Fuse Cutter and Cap Crimpers are especially constructed pliers made for the purpose of fastening blasting caps securely to fuse. They are equipped with a special fuse cutter, and one handle is made round and pointed for punching holes in sticks of dynamite in which the detonators are placed. These crimpers are nickel-plated, packed in cartons, 12 to the box.

Storage Magazines

The Hercules Powder Co. carries a complete line of sidewalk and steel storage magazines, having a capacity of from 1 to 924 fifty lb. dynamite cases.

Consult with the Hercules Service Division on All Your Blasting Problems. For Further Detailed Information Write for Our Book, "Hercules Products".

ILLINOIS POWDER MFG. COMPANY

General Offices
1652 Pierce Building, ST. LOUIS

Works: GRAFTON, ILLINOIS

Branch Offices

Steger Bldg., 28 E. Jackson Bl.
CHICAGO

1419 Central Bank Bldg.
MEMPHIS, TENN.

406 Victor Bldg.
KANSAS CITY, MO.

And Many Other Distributing Points

Makers of

"Gold Medal Dynamite"

Manufacturers Also of

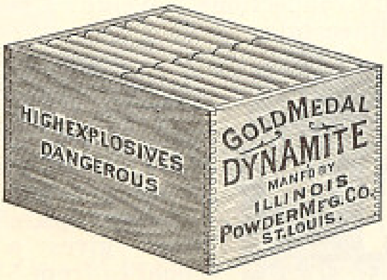
BLACK DIAMOND PERMISSIBLES AND BLASTING SUPPLIES——BLASTING POWDER

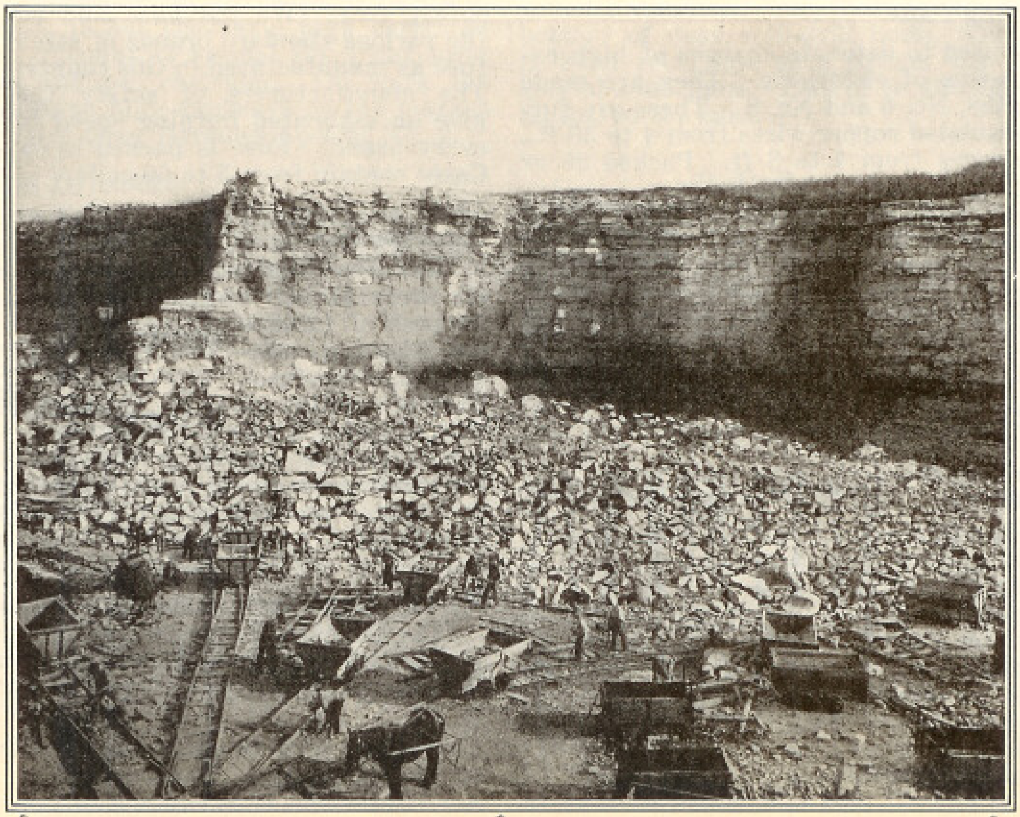
"Gold Medal" Dynamite—A variety for every need.
"Gold Medal" Gelatin—All Grades. All Strengths.
"Gold Medal" Products are Dependable—Uniform.

No requirements too small to receive our careful attention. No demand too large for our facilities.

Blasting Supplies

The Illinois Powder Mfg. Co. carries a complete stock of Blasting Machines, Blasting Caps, Safety Fuse, Cordeau-Bickford Detonating Fuse, Electric Blasting Caps, Leading and Connecting Wire, Thawing Kettles, and all other Blasting Supplies. Every order is given careful and prompt attention. Your requirements are solicited.





The Result! It Certainly Shows For Itself
"Gold Medal" Dynamite—"Stronger and Goes Further"

Coast Manufacturing and Supply Company

LIVERMORE, CALIFORNIA

Manufacturers of Safety Fuse

The manufacture of Safety Fuse is no longer an art. Scientific management, coupled with complete chemical control of raw materials and finished products, plus mechanical accuracy, make it an exact science.

Every brand of Fuse manufactured has some definite, commonsense reason for its existence. A complete knowledge by the user of Safety Fuse, of the function of each brand, means the elimination of needless and avoidable mis-fires.

Three-fourths of all mis-fires are preventable by the use of care when making up primers.

The following instructions carefully carried out will cut mis-fires to a practical minimum:

Purchase Safety Fuse made in America.
Select Safety Fuse with reference to its suitability for use in your operations, rather than for its position on the price list. The highest priced fuse may not be the one most suitable for your operations.
Give Fuse cool, dry storage.
Cut Fuse with a clean, sharp instrument.
Be certain that damp fuse - ends are not inserted into the caps.
Fuse must be cut squarely across and be in absolute contact with cap-composition to give good results.
To waterproof the joint of Safety Fuse and cap, use nothing but CELAKAP.

Every avoidable missed hole costs money. A missed hole in a stope may cost only a few cents, while one in development work may mean a loss of dollars.

Safety Fuse, as it leaves the factory, will not flash, nor hang fire. Improper storage, careless handling, and contamination by liquid oils, light greases or lubricating compounds will give needless trouble and poor results.

Safety Fuse for domestic shipment is packed in both wooden and fibre cases. For export shipment, fuse is packed in wooden cases only, paper lined at no extra charge, and tin lined when desired by the customer, at an aded net cost of $.25 per thousand feet of fuse.

The cut illustrates a new style of packing, designated "Reel Packing". The reels are made of light metal, and each contains 3,000 feet of fuse, in not less than two pieces, and usually not over three pieces, to each reel. This makes for economy, and eliminates waste ends. This style of packing should meet with the approval of mining and quarrying companies who make their primers at a central point, and whose consumption is not less than ten cases (60,000 feet) monthly. There is no additional cost for reel packing. Fuse reels for domestic use are packed in fibre containers; those for export in wooden cases.

SIZES OF CASES—OUTSIDE DIMENSIONS

Feet	WOODEN		FIBRE	REELS	
	Domestic	Export	Domestic	Wooden	Fibre
6000	34 x 14 x 14"	32 x 14 x 14"	19¼ x 12⅞ x 10⅞"	17¼ x 14 x 14"	16 x 13¼ x 13¼"
3000	21¼ x 13¾ x 11"		13¼ x 6¾ x 10½"		
1000	12¼ x 14 x 7½"				

Celakap

CELAKAP is a preparation of gums held in suspension in a liquid that is reasonably quick-drying, and non-injurious to Safety Fuse. It is transparent and colored red; the transparency allowing the cap to be visible after being dipped. Blasting accidents have occurred through black fuse having been capped, then dipped in opaque material, and attempts made to light the wrong end, the capped portion being left on the outside of the hole in these cases.

Fuse manufactured by the COAST MANUFACTURING AND SUPPLY COMPANY can be obtained through any powder company serving the trade in the Western States.

AVERAGE WEIGHTS AND PACKING OF SAFETY FUSE

Brand	Cases Export—Wooden			Cases Domestic—Fibre			Reels
	6,000-ft.	3,000-ft.	1,000-ft.	3,000-ft	1,000-ft.	500-ft.	3,000-ft.
Triple	115 lb	61¾ lb	23 lb	49½ lb	17¼ lb	8¾ lb	53 lb
Double	115 lb	61¾ lb	23 lb	49½ lb	17¼ lb	8¾ lb	53 lb
Bear	110½ lb	59½ lb	22¼ lb	47¼ lb	16½ lb	8⅝ lb	50¾ lb
Victor	110½ lb	59½ lb	22¼ lb	47¼ lb	16½ lb	8⅝ lb	50¾ lb
Pacific	104½ lb	56½ lb	21¼ lb	44¼ lb	15½ lb	7⅞ lb	47¾ lb
Blue Label	110½ lb	59½ lb	22¼ lb	47¼ lb	16½ lb	8⅝ lb	50¾ lb
Comet	112 lb	60¼ lb	22½ lb	48 lb	16¾ lb	8½ lb	51½ lb
Comet Special	110½ lb	59½ lb	22¼ lb	47¼ lb	16½ lb	8⅝ lb	51½ lb
Eclipse Special	112 lb	60¼ lb	22½ lb	48 lb	16¾ lb	8½ lb	51½ lb
Dreadnaught	109 lb	58¾ lb	22 lb	46½ lb	16¼ lb	8¼ lb	50 lb
Sequoia	115 lb	61¾ lb	23 lb	49½ lb	17¼ lb	8¾ lb	53 lb

The average tare on all brands is as follows: The above are average gross weights.

Wooden	Fibre	Reels
6,000-ft. case 25 lb 3,000-ft. case 16¾ lb 1,000-ft. case 8 lb	3,000-ft. case 4½ lb 1,000-ft. case 2¼ lb 500-ft. case 1¼ lb	3,000-ft. case 8 lb

Export Packing—Approximately ⅝ cu. ft. per 1,000 ft. of fuse.

THE ENSIGN-BICKFORD CO.

SIMSBURY, CONN.

Manufacturers of

Safety Fuse For All Purposes
and
Cordeau-Bickford Detonating Fuse

CORDEAU-BICKFORD

Products

Safety Fuse; Cordeau-Bickford Detonating Fuse.

Cordeau-Bickford is a detonating safety fuse consisting of a lead tube filled with trinitrotoluene. It has been manufactured by The Ensign-Bickford Company during the past seven years and may be obtained direct or through any of the explosive companies.

This type of detonator is waterproof, safe and easy to handle, and will explode a charge of explosive throughout its entire length and also any number of separate charges instantaneously.

Cordeau-Bickford cannot be set off by fire, friction, or any ordinary shock.

Cordeau is particularly adapted to well drill blasting where large columns of explosives are fired, where it is desirable to break the charge in the drill hole, or where a great many holes are to be fired at one time.

Cordeau is run from the top to the bottom of the drill hole in contact with the explosive charge so that it acts as a continuous detonator, with the result that a more complete and quicker detonation of the explosives is obtained. On account of this, there is a greater shattering effect on the rock, and the secondary blasting is therefore reduced.

Cordeau is also used in the "Coyote" or Tunnel and Pocket method of blasting.

The explosive manufacturers use Cordeau for determining the rate of detonation of their explosives.

Write for booklets on Cordeau and Deep Well Blasting.

Cordeau-Bickford was used to detonate the 62,350 lbs. of explosive used in this blast. Tonnage of cement rock broken, 370,000.

THE ENSIGN-BICKFORD CO.

SIMSBURY, CONN.

Manufacturers of

Safety Fuse For All Purposes
and
Cordeau-Bickford Detonating Fuse

Products
Safety Fuse; Cordeau-Bickford Detonating Fuse.

It is essential for the purpose of safety and economy to purchase a brand of fuse adapted to the work for which it is to be used.

In quarrying, the work may be dry, damp, or wet; while in metal mining, the work is generally either damp or wet. Dry work means that the fuse does not come in contact with moisture; damp work means that there is moisture present either in the drill hole or in the tamping material (mud-capping, for instance, is generally classed as damp work); and wet work means that the fuse is actually exposed to the direct action of water in the drill hole. In underground work of various kinds, the following characteristics in fuse, in addition to the waterproofing quality, are important: Regularity in burning, freedom from lateral sparking and excessive smoke, ability to withstand reasonable tamping, flexibility, and an exterior white finish which makes it easily distinguishable in the dark.

The standard burning speed of all our brands of fuse at sea level, with the exception of Charter Oak and Clover, is ninety seconds per yard when burned in the open with an allowable variation of 10% either way from standard. Clover and Charter Oak have a standard burning speed of one hundred twenty seconds per yard under the above conditions with an allowable variation of 10% either way from standard.

TAPED FUSE

The original waterproof fuses were all of the tape variety. Low temperatures affect the pliability of taped fuse and in work done on the surface in cold weather, the countered fuses such as Beaver, Charter Oak, Crescent, and Clover are best adapted in preference to Single Tape or Double Tape.

Single Tape

For use in dry or damp work.

Double Tape
For use in wet work. This fuse has two tape coverings which add strength as well as waterproof qualities.

COUNTERED FUSE

Beaver and White Charter Oak
For dry or damp work, Beaver or White Charter Oak is quite generally used, Beaver being selected by those who have preference for the ninety second standard burning speed, and White Charter Oak by those who prefer the slower standard of one hundred twenty seconds per yard.

Gray Charter Oak
Gray Charter Oak is a later development in manufacture which has enabled us to improve the waterproof quality without adding to the cost. Where the requirements for waterproofing are beyond the limits of Beaver or White Charter Oak, we recommend the adoption of Gray Charter Oak.

Gray Charter Oak will meet all the varied requirements of quarry work and is especially recommended for use in the quarries.

Crescent, Anchor, Clover
Where the two principal elements are waterproofing and regularity of burning speed, Crescent or Anchor are usually preferred; but where other considerations enter in, such as freedom from side spit, freedom from excessive smoke, and economy of time due to slower burning speed, Clover is preferred because it has even greater waterproof qualities than Crescent, and has, in addition thereto, the above mentioned advantages. The paper tape used on Clover enables the fuse to be subjected to extreme climatic changes and long storage without deterioration.

Avoid lacing, half hitching or the kinking of fuse, especially when the fuse is going to be used in a wet drill hole.

Price lists, sample cards, and further information will be gladly furnished on application.

THE NATIONAL FUSE & POWDER CO.

DENVER, COLO.

Manufacturers of

Safety Fuse for All Kinds of Blasting

Product

Safety Fuse for All Kinds of Blasting.

The watchword for all blasting operations is EFFICIENCY, with due regard for economy and safety.

A careful study of the various classes of blasting operations and the exacting duty imposed upon Safety Fuse under widely varying conditions has led to the manufacture of standard NATIONAL Brands of Safety Fuse which are constructed to perform certain specified work at the lowest possible cost consistent with safety. It is therefore essential that a careful survey be made of the class of work to be done, with the view of selecting proper type of Safety Fuse. In case there is any question in the mind of the Mining Company as to the proper Fuse to be used, we will be glad to extend our advice.

The NATIONAL Brands of Safety Fuse are the result of years of intensive research work, and only such materials as stand up to most rigid specifications are used in their manufacture, the result being that we believe we produce a Safety Fuse which goes to make the most for Efficiency in blasting operations.

Taped Fuse

Taped Fuses have long been Standard types in view of their added strength and excellent resistance to rough treatment.

Single Tape

For use in dry or damp work.

Double Tape

For use in wet work.

Triple Tape

For use in very wet work, where exposed to rough treatment.

Countered Fuse

Owing to the fact that taped fuses are more susceptible to widely varying weather conditions, the Hard-Finished Cotton Countered varieties are coming more into use.

Jute

For use in open, dry work. Not to be used in drill holes.

Sylvanite

For use in damp work. Suitable for coal or metal mining, and agricultural blasting purposes.

White Monarch

For use in wet work—double countered.

Black Monarch

For use in very wet work—double countered.

Bear and Acme

For use in very wet work. A strong taped, Gutta Percha fuse—single countered.

Shield

For use in very wet work. A strong taped, Gutta Percha fuse—single countered.

Recommendations

In extremely wet work, Black Monarch, Bear or Triple should be used.

If work is to be done in extremely cold places, Sylvanite, Monarch or Bear should be used in preference to Single, Double or Triple.

Fuse should be stored in a cool, dry place and not taken into the mine except for immediate use.

When primers are being made up, always cut off a short piece before inserting in the cap.

A sharp, clean cutting edge should be used and the fuse cut squarely across.

Speeds of Burning

All our brands have a standard speed of 126 seconds per yard when burned dry in the open at an elevation of 5,280 feet, with an allowable variation of 10% either way from the standard.

Prices

Price Lists and Sample Cards furnished on request. Let us aid you in solving your fuse problems.

Packages

Fuse is packed in a roll, containing two 50-foot coils, and in the following sized cases:

WOOD		FIBRE	
No. 0	500 ft.	No. 0	500 ft.
No. 1	1000 ft.	No. 1	1000 ft.
No. 2	2000 ft.	No. 2	2000 ft.
No. 3	3000 ft.	No. 3	3000 ft.
No. 6	6000 ft.		

CALIFORNIA CAP COMPANY

OAKLAND, CALIFORNIA

The output of a factory devoted exclusively to the blasting cap end of the explosives business.

Uniformly dependable. Suitable for all climates. Obtainable through dealers and powder companies.

Blasting Caps

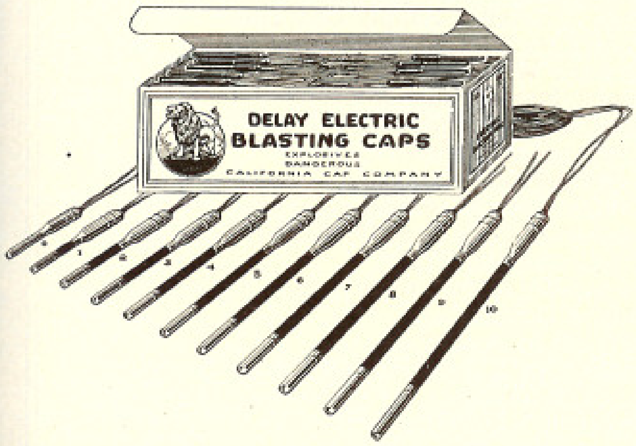
Standard No. 6 and No. 8 strengths; packed 100 in a tin box, 50 boxes (5,000) to the standard case. Smaller quantities in suitable packages to order.

Electric Blasting Caps

No. 6 and No. 8 strengths with insulated copper wires, one yellow and one black, from 4 to 20 ft.; longer lengths to order; also iron wires 4 to 8 feet. Packed 25 and 50 in cardboard cartons, 10 cartons in wooden case. Special waterproof insulations and reinforced cap shells for deep well work to order.

Electric Igniters, same as above without caps.

Delay Electric Blasting Caps

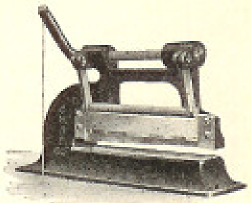


Ten different delay periods capped and waterproofed ready for use. No. 6 and No. 8 strengths with insulated copper wires, 4 to 20 ft.; one yellow and one black leg to minimize possibility of error when making connections.

Standard case contains 50 each 1st to 10th delay. Other lengths and special assortments to order from factory.

Delay Electric Igniters, ten different delay periods; uncapped, otherwise same as above.

Fuse Cutter



CM&S Bench Type; foot operated; capacity 20 pieces at a time, making clean, square cuts without fraying.

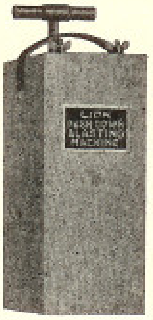
Weight approx. 5 lbs.

Cap Crimpers

The broad jaw CALIFORNIA type fastens cap securely to fuse. No. 1, crimping pliers only; No. 2, combination crimper and fuse cutter; dull nickel finish; packed in cartons 12 to the box.

California Bench Crimper

Hand or foot operated; four tempered steel jaws make dependable, all round crimp; mechanically correct; easily adjustable; weight 5½ lbs.; fuse cutter attachment using safety razor blades easily changed.



Blasting Machines

"DAVIS", twist handle; pocket sizes; 5 and 10 cap capacities.

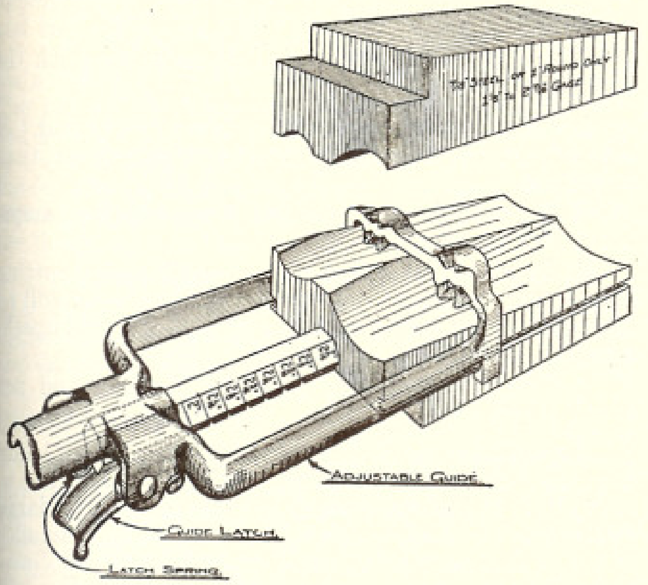
"LION" Pushdown; 10 and 50 cap capacities; wooden case; weight 6¼ and 23 lbs. respectively.

"REX", the only portable blasting machine having high amperage for combination circuits; capacity 520 watts (4½ amperes at 120 volts). Rated 1 to 50 caps in series or 1 to 4 multiple-series groups, making total capacity 200 caps; weight 25 pounds; all metal; spring operated; action of generator controlled by button; very serviceable and dependable.

"THE DETONATOR"

Published monthly, distributed without charge, features regularly a Blasting Talk of practical interest. Send name and address, mentioning occupation. 1540 San Pablo Ave., Oakland, Cal.

The manufacturers of drill-steel sharpeners are continually making the machines more nearly foolproof. One of the latest improvements for assuring better bits is the use of double-bored gaging blocks with an adjustable latch guide. The wide range of these blocks permits the operator to gage accurately an entire normal run of steel on the one set of blocks, and these adjustments for the various gages require only the pressure of a finger on the adjustable latch guide.



Double Bored Gaging Blocks

An interesting but less common cause of stuck steel is the feeding of too much or too little water through the hollow drill steel. When too little water is fed a mud collar frequently forms behind the drill steel, which makes it difficult to extract the latter. Sometimes when drilling into rock bearing metallic ore, and too much water is fed, a mineral separation takes place. The gangue is sludged off, and the drill pounds away ineffectively on the metallic residue, finally becoming stuck. Sometimes dry drills are run in abrasive ground. The steel soon heats up, and the temper is rapidly burned out of the bit. This condition may be remedied by using a water feed or a wet drill.

Sometimes the shank portion of hexagon steel becomes so worn that it permits the steel to slip in the rotative sleeve, or the lug on round steel becomes worn or broken off, with the same result. The drill steel will then be hammered into the ground without rotating and will soon become stuck. The only remedy for this is to keep the shanks in proper condition. The same results are obtained when use is made of worn or broken drill parts, principally worn pawls, chuck and bushings, and broken pawl springs and rifle bars. The only remedy for this fault is to replace the worn or broken parts.

The rotation of some drills may be too weak for the rock conditions. This, however, is exceptional, because rock-drill manufacturers have strengthened the rotative power of the drills up to a practical limit. Frequently, drill trouble is attributed to weak rotation when that is far from being the true cause.

Unequal cutting may easily take place when drilling into a seam or in fitchery ground, and this throws the steel out of line and sticks it. Drilling into brecciated ground sometimes causes pebbles or small bits of rock to fall behind the bit, and those wedge against the steel and the drill hole, stopping rotation. In some limestones and other calcareous formations the water mixing with the cuttings will form a mud collar back of the bit.

In all of these instances mentioned it becomes a question of loosening and removing the stuck steel. There is one popular method of performing this operation that should not be followed, and that is to pound away on the drill steel with a 16-lb. double jack. This manner of loosening the steel is common, but usually the only real results obtained by it are bent steel, broken drill parts, strong back, and increased vocabulary. Usually the steel itself stays stuck. Another method, advocated for obvious reasons, has to do with the proper lubrication of the machine. When the steel is stuck, fill the back and front cylinder pockets with oil, open the throttle and 99 per cent of the time the steel backs out of the hole without any further trouble. A slight blow loosens the drill steel and properly lubricated rotative parts take care of the rest.

The increased ease of operation and the greater speed of drilling of properly lubricated drills should convince the operator that this matter ought to be properly considered. Unfortunately a great number of operators still think that axle grease is good enough, others think cylinder oil will do, and others don't think.

Representatives of either oil companies or rock-drill manufacturers are always pleased to consult with and give to mine operators the benefit of expert knowledge and long and varied experience.

Abstracted from article by D. E. Dunn, of Ingersoll-Rand Company, written for Engineering and Mining Journal.

Hardening and Tempering Rock Drill Steels*

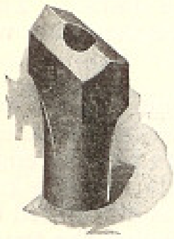
Rock drill steel does not break so long as it keeps its cutting edges and penetrates the rock with each blow of the hammer. The penetration of the drill into the rock is the cushioning effect which absorbs the force transmitted to the bit by the hammer of the machine. As soon as the cutting edges wear off and become dull and the bit ceases to penetrate the rock, there is no longer any cushion to take up this force. The drill can only bend with each stroke of the hammer and this repeated bending many hundred times a minute causes the drill to break very quickly. It is, therefore, of the utmost importance that every action in forging, hardening and tempering which has to do with producing and keeping a keen cutting edge be carefully attended to.

Bits

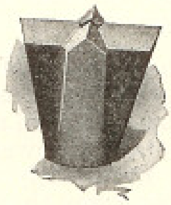
The question as to the type of bit to be used is largely dependent upon the nature of the rock to be

*From Colonial Rock Drill Steel Book.

drilled, and the type of machine used. The most common type in use, both for hollow and solid, is the well-known cross bit, but in many cases there are other and approved forms of bit which will prove much more efficient.



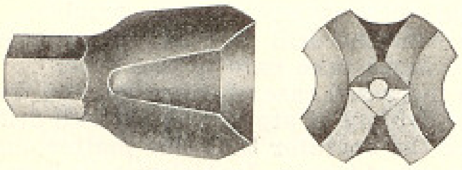
The Carr Bit on Hollow Round Steel



Cross Bit on Hollow Round Steel

For example, in the copper mines of Northern Michigan a machine of the light one-man type is generally used with drill steel either ⅞″ or 1″ hexagon. By using the Carr type of bit in this machine an additional footage of perhaps 30% is gained over the practice with the formerly used Cross bit. This, however, is not a criterion for other mines, this bit being suitable for those mines having hard and tough rock free from small faults or slips. Hard slips give trouble when the Carr bit is used, as this form of bit is likely to follow one of the slips and be deflected from the course of the drill hole, causing the steel to bind and a great increase in breakage.

A Double-Cross Bit has many advantages over the regular Cross Bit. As this bit revolves in the hole the impressions cut in the rock intersect one another in such a way that the work is more evenly distributed over the entire cutting edge. Unfortunately, however, this type of bit is difficult to forge.

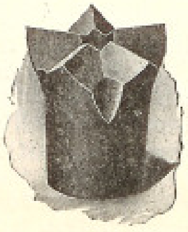


Double-Arc Bit

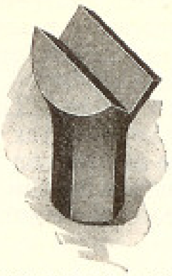
A new type of bit known as the Double-Arc with two circular cutting edges, as shown in the illustration, is strongly recommended as one not only possessing many of the advantages of the ordinary types of bit, but also one that can be very easily machine-sharpened and hardened.

The Double-Arc bit is harder to make up for the average blacksmith unless he is provided with special dies, dollies and a standard drill-sharpening machine. Otherwise we would not urge it unduly.

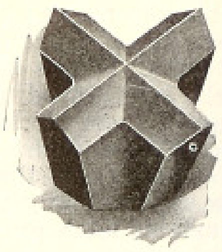
Four-Point Double Taper Bit on Solid Round Steel



Five-Point Bit on Hollow Round Steel



Two-Point or Double Chisel Bit on Solid Hexagon Steel



X Bit on Solid Round Steel

Whatever type is selected it must be with the knowledge—

1. That the bit must cut rather than pound. It should act as a wedge and fracture rather than pulverize.

2. It should be so designed as to allow ample room for ejecting the cuttings.

3. It must be symmetrical and have cutting edges true and even, otherwise a rifled hole will be the result with consequent liability to greater breakage of the drill.

4. The bit must be properly dressed and not overheated.

An angle of 90% is generally accepted as being correct for the cutting edge, while a taper of one to four is the general practice. Unnecessarily large gauges of bits should not be used, as the smaller the hole is started that will give the desired diameter, the faster will be the drilling and the less will be the power consumed.

Care should be taken at all times to protect drill steel bars from cracks or deep scratches so as not to form a starting point for breaks. Bars are commonly stamped with the brand of the maker's name only at the extreme end.

Bars should not be nicked while cold with the chisel, but should be heated and cut off while hot. A much better practice would be to install a hack saw to cut the bars smooth and even on the end. This will not only avoid any danger of cracking, but would also save subsequent labor which would otherwise be necessary in grinding the shank smooth and even. Shops which are equipped for handling a large number of drill bits would do well to install a hack saw for this work.

Heating

Heat is the important factor in the use of steel for tools of any kind, and rock drill bits are fully as sensitive to the effect of heat as any other kind of tool. Forging drill bits should be conducted with great care. The proper temperature for forging both hollow and solid drill steel is 1550° F., and it must not be higher than 1600 degrees, otherwise the steel will be overheated and lose the power of retaining its clean cutting edge. Do not attempt to complete the forging at one heating should the color fall below a red. In such a case place the steel back in the furnace and bring it up again to the necessary temperature; forging the steel below the proper working heat distorts its structure and brings about a brittle condition. In forging, it is better to finish with repeated light blows rather than by attempting faster reduction with a heavy blow.

Modern methods are rapidly doing away with the use of the old-fashioned forging with coal or coke fire. For best results, the use of an oil or gas-fired heating furnace is absolutely essential. These furnaces are now being built and can be obtained from several well-known makers. In cases where it is not practical or desirable to purchase a furnace one of simple design can be constructed in any blacksmith shop, the burner only being purchased. The sides and bottom of the furnace should be made from boiler or tank plate ¼″ thick of the following dimensions: Bottom 36″ long by 18″ wide; front and back 36″ long by 14″ high; sides 18″ long by 14″ high. Space for the door is cut in the front plate. Sides and bottom are lined with fire-brick. The top of the furnace should be made removable and built of fire-brick, held together by steel bands in the ordinary fashion. The legs for supporting the furnace can be made of common steel bars. The bottom of the furnace should be about 30″ from the floor.

Gas is preferable for fuel wherever obtainable. The oil, if used, should be kept in a storage tank below the level of the furnace in order to reduce the danger of fire.

Critical Temperature

When the number of drills to be hardened each day is large, two furnaces should be used, one for the forging and one for the hardening. A pyrometer should be installed in connection with each furnace to determine the exact temperature and to enable the blacksmith to keep the furnace at a regular even heat. When a pyrometer is used frequent check should be made on its registering, at least once a week.

For the purpose of investigation, when a pyrometer is not available, take a piece of drill steel bar about one foot long, nick it in six or eight places about one inch apart, place one end of the piece in the furnace and heat it until it is nearly white, letting the heat run gradually out toward the other end of the piece to a dull red and then quench in cold water. Break the piece with the sledge at the places where it was nicked and examine the fracture. The fracture which is the finest and has the most silky appearance is the one at which the heat was nearest to the critical temperature. By this practice a skilled smith can readily determine the proper heat, and it is commonly used.

Magnet Shows Critical Point

Figure 1 shows an inexpensive electrical indicator for determining when the steel has reached the decalescent point. This is an ordinary horseshoe magnet hung from a fibre or other non-conducting support. At the upper end of the support is a copper contact for closing an ordinary light circuit. This indicator is more serviceable in the shop than an ordinary horseshoe magnet hung from a cord. When the heated bit is pressed against the copper plate the light will flash if the steel is at too low a temperature for quenching. The correct heat for quenching is when the magnetism leaves the steel. This indicator gives one of the two necessary facts about the temperature of the steel for quenching. It is the fact that the steel is hot enough, having passed the critical temperature.

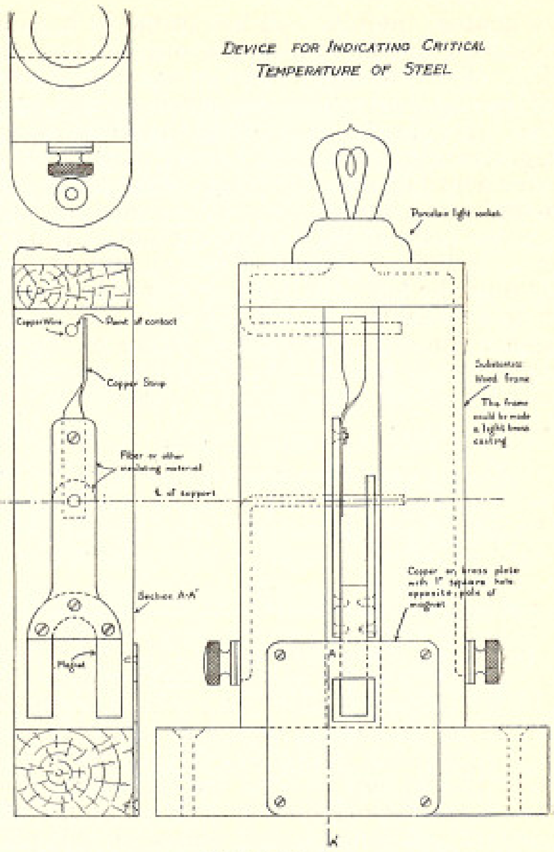


Figure No. 1

Hardening

Hardening should never be done at the forging heat. A very good practice is to give the bits a partial annealing by placing them as soon as the forging is completed in a box filled with lime, covering them over, and leaving them in the lime until cold.

Harden the bits, that is, quench them while the heat is rising, never when it is falling. The bits should be arranged in the furnace in such a way that, whenever one is withdrawn for quenching, those remaining in the furnace are moved up towards the place where the temperature is the highest, the new bit taking its place at the end of the line. The critical temperature below which drill steel will not harden is about 1375° F., and it must be remembered that a certain amount of heat is lost during the passage of the bit from the furnace to the quenching tank; consequently, the temperature of the furnace must be maintained at a point sufficiently above the critical temperature to take care of this fall. Bits must be heated evenly all through, but never any farther back than is necessary. If the center is not the same temperature as the corners, it will flatten out and impede the cutting. The proper temperature at which to keep the hardening furnace is 1450 to 1500° F. As soon as the bits reach this temperature, they should be withdrawn and plunged vertically in the water.

Quenching

The quenching tank should be provided with an inlet at the bottom, and an overflow just below the top. It is best to have a continuous strong flow of water through the tank, so that it can be kept constantly cold, for if the water is allowed to become heated, the bits will not properly harden. A wire screen should be placed about $\frac{3}{4}''$ beneath the surface of the water, unless an automatic arrangement for tempering, as described hereafter, is installed. Be careful to see that the drills stand perfectly straight, so that they will not harden to a greater depth on one side than on the other. When cold withdraw, and temper by permitting the heat left in the body of the drill to run out of the cutting edges. A little experiment will show how long the drills must be left in the water to produce the right temper. Color to which drills should be drawn can be varied somewhat as the conditions of the ground demand. It is necessary to pull the drills from the quenching tank before they are cold.

When water is scarce, instead of introducing a constant stream, run a pipe from the airline to the bottom of the quench tank. This will keep the water constantly agitated, and will prevent its heating up too rapidly.

Tempering

Automatic tempering is desirable wherever possible. An apparatus can be made with a rotating platform placed beneath the surface of the water, at an angle in such a way that a portion of the platform, when it is highest, is just below the surface of the water. Above and joined to the platform is a framework built to hold a number of drills in upright position. A drill placed on this platform at the highest point is carried as the platform revolves around the tank, getting gradually deeper in the water, until it get to the opposite side, after which it gradually emerges. The best of such an arrangement is the uniformity in tempering which it gives. The depth of submersion in the water can be arranged to suit the requirements. This gradual submersion of the steel in the water produces a blending of the hardened and unhardened portions of the steel, which adds to its strength.

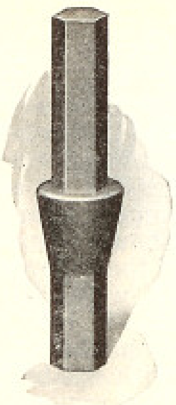
Shanking

Shanking should not be done at one operation. Form the collar at one heating and the finishing of the shank and lug at another. After the shank is completed, place the steel in the furnace and reheat to the forging heat; then place in an iron box and cover over with powdered lime and allow to cool off slowly. After this, reheat to 1450° F. and immerse the shank in oil. Great care must be taken to see that the steel stands perpendicularly, permitting the oil to come to one-fourth of an inch above the lug. The temper of this shank should then be drawn by reheating. The extent of this reheating will depend a great deal on the type of machine used and the hardness of the rock which is to be drilled. If the shank shows a tendency to be brittle, it might be desirable to draw the temper to about 600° F.

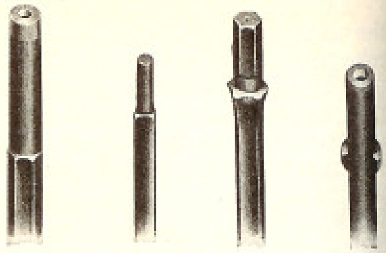
The end of the shank must be kept square and smooth, with the edges slightly rounded.

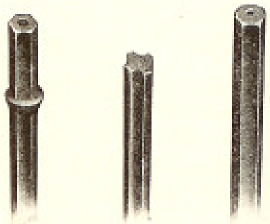
Inspecting

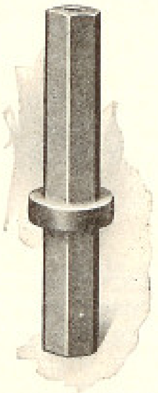
After tempering, each piece of steel should be carefully inspected before it is sent to the drills, to make sure that the bit and shank have been properly formed, that the gauge of the bit is of the



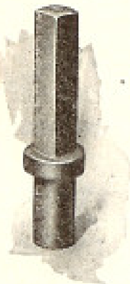
Hexagon Shank with Tapered Collar on Hexagon Steel







Hexagon Shank with Collar on Hollow Hexagon Steel



Square Shank with Collar on Hollow Round Steel

correct size, and that it has been properly hardened and is free from cracks or any imperfections which might result in breakage.

The shank end of the drill steel must be ground off square, for, if not, the hammer of the drill cannot deliver a direct blow and if the blow is transmitted through a part which is not in direct alignment the effect is the same as the operating of an engine with a bent piston rod. For the same reason the end of the striking blow or hammer in the drill must be ground off square and smooth, and must not be allowed to become hollowed out.

In concluding, we may summarize in saying:

Summary

1. Discourage the practice of operating with a dull bit, and remember that the only reason drill steel will drill rock is because of the cushioning effect of penetration at every blow delivered.

2. To harden successfully, plenty of time must be given to the heating and always leave the steel in the furnace long enough to insure its being heated uniformly and thoroughly. This may be best accomplished in a slow fire, and only by slow uniform heating is it possible to secure the required uniformity in hardness.

3. Never heat either the bit end or the shank end, preparatory to forging, higher than 1600° F. This may mean a little more work on the part of the blacksmith, but the gain in quality of the finished drills will greatly offset the slightly additional expense in forging.

4. After hardening and tempering either bit or shank always quench at the critical temperature on the rising heat.

5. Overheating a piece of steel preparatory to forging produces coarseness of structure which cannot be restored or refined by merely allowing it to cool and then subjecting it to a tempering operation.

6. The degree of hardness that may be given to the cutting end of a rock drill bit is determined by the conditions of the ground under which it has to work, and when a bit is quenched at the critical point the degree of hardness may be varied by varying the rate of final cooling.

7. When tempering shanks do not overlook the fact that density and toughness provide wear-resisting qualities, and that hardness, except on the extreme outer surface, is not essential or desirable. Subject the part for a distance of 2″ below the lugs or collar to the heat treatment.

8. Keep the chuck bushing up to size and remember that the worn end of a chuck bushing will prevent the transmission of a square, direct blow. This same statement will apply to the size of the drill shank.

9. Steels lying too long in the fire, especially when not turned about, are liable to show soft spots in hardening, due to a slow decarbonization which takes place.

10. Watch your drill-sharpening machine for worn dies and dollies. Worn parts of a sharpener often cause poor bits to get out. These bits are often feathered badly, which means that a feather or tip of steel is left on one or more of the corners. These feathers, of course, break off as soon as they are put in the drill and cause a rapid loss of gauge.

11. Watch your air pressure at your sharpening machine. Most sharpeners should have at least eighty pounds at the machine and if the machine is running on less pressure and the smith tries to forge the bit at the proper temperature, it gets cold before he can get the corners on, so to get out his work he usually yields to the temptation of putting the steel through hotter than he should. If the pressure were high enough he could complete the forging of his bit at the proper temperature before it got too cold.

12. Either keep the heated tool moving about in the quenching bath or keep bath agitated, otherwise soft places may result, due to the steam which is formed around a heated steel upon being plunged into the water.

13. To get uniform results in hardening, a good supply of liquid should be provided so that the temperature of the bath will be kept as nearly as possible a constant.

WEIGHT OF SOLID DRILL STEEL—PER FOOT

Size	Octagon	Hexagon	Cruciform Rocky Mountain	Quarter-Octagon	Round
⅝	1.10	1.15	....	1.25	1.04
¾	1.58	1.66	1.35	1.80	1.50
⅞	2.16	2.25	1.70	2.45	2.04
1	2.82	2.94	2.20	3.20	2.67
1⅛	3.57	3.73	2.80	4.05	3.38
1¼	4.40	4.60	3.35	5.05	4.17
1⅜	5.33	5.57	4.02	6.10	5.04
1½	6.35	6.62	4.75	7.25	6.00
1⅝	7.45	7.76	5.50	8.50	7.05
1¾	8.64	9.00	6.25	9.80	8.17
1⅞	9.91	10.32	7.10	11.30	9.38
2	11.29	11.76	8.00	12.90	10.68
2¼	14.29	14.90	9.75	16.35	13.52
2½	17.64	18.48	11.55	20.20	16.69

Ideal Shop For Sharpening Drill Steel

Primary Requirements of a Sharpening Plant

Primarily a drill-steel plant having one mechanical sharpener should be designed so that the output of the smith and his helper may be doubled by the addition of two men, without any increase in the original shop equipment being necessary, and to provide for possible growth, it should be so constructed that by adding space and certain features of equipment to one end only of the building the capacity may be increased further at slight expense without making any change in the original equipment; that the various operations required to make the drill steel and to reforge and temper used steel are performed with the fewest possible movements and with the least amount of exertion on the part of the operator; and that the character of the work when executed conforms with the established standard for the existing conditions.

To secure these results the building should be of such size that the various machines and their appurtenances may be placed in the most advantageous position. It should be built of materials that are accessible and in conformity with the standard surface equipment of the mine. It should be lighted in such a manner that the piece being worked upon and the operating end of the machine employed are clearly visible to the operator, so that his vision of the parts is not obstructed by shadows; in addition, to meet the requirements of a shop of the size and type herein described, certain features of equipment are recommended in Table 1.

In order to obtain maximum efficiency in a drill-steel plant it is essential that the transportation of the drill steel be accomplished expeditiously and with a minimum effort, for, regardless of how suitable the mechanical equipment may be, it is impossible to secure and maintain maximum production from the machines and furnaces if a suitable means of transportation conforming to the requirements of the plant is not provided.

To meet the requirements of the type of plant described in this paper it is recommended that the shop, Fig. 1, be equipped with a permanent track and turntable, the gage of which corresponds to the standard gage of the mine or quarry tracks, provided such gage does not exceed 36 in. For transporting the drill steel to and from the shaft, or loading platform, a division car of the Copper Queen

Tempering

1 Rotary quenching and tempering machine (Homestake type), with 1 H. P. motor.
1 Electric switchboard for tempering-machine motor.
1 Oil-quenching tank with syanide receptacle.
1 Ventilator with hood for syanide receptacle.

Racks, Tables and Accessories

1 Inspection and bundling rack with incline, equipped with one gage cabinet.
1 Storage rack for drill-steel bar stock.
1 Storage rack for finished drill steel.
1 Used steel table.

Sanitary Equipment

1 Sanitary drinking fountain.
4 Steel double-deck lockers.
2 Wash basins.
1 Sanitary towel rack.
1 Urinal.
1 Flush bowl.
1 Emergency cabinet.

General Equipment

1 Work bench equipped with 5-in. machinist's vise.
1 Desk with drawers and hinged top.
1 300-lb. anvil.
1 Set of hand chisels and sledges.
2 500-watt Mazda lamps with reflectors.
1 60-watt Mazda lamp with reflector.
Water piping.
Compressed-air piping and hose equipped with Davies blow-gun.
Waste piping.
Oil piping.
Electric wiring.
Concrete floor.

ARRANGEMENT OF DRILL HOLES IN TUNNELS

The arrangement of drill holes is influenced by local conditions, but nearly all the systems adopted in American mining tunnels and drifts may be classified under three heads, according to the type of cut employed.

The "cut" or "cut holes" are those which are pointed in such a manner that, when blasted first, they remove a core or wedge of rock from the solid face, thus decreasing the work to be done by the remaining holes.

The wedge or "V" or center cut, the one most commonly employed, consists of several pairs of holes directed toward each other from opposite sides of the heading. They break out a wedge-shaped prism, usually extending from floor to roof. Figs. 2, 2a and 3 show several arrangements of

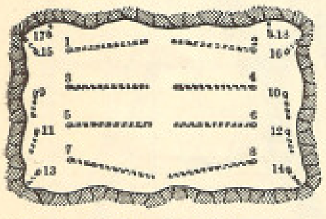


Fig. 2. Wedge-Cut Round of Holes.

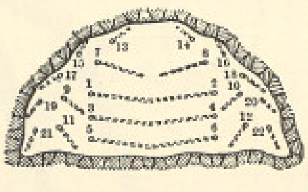


Fig. 2a. Wedge-Cut Round for Arched Headings.

wedge cuts. In Fig. 2, holes 1 to 8 comprise the cut and are blasted simultaneously. Side holes 9 to 14 are next fired together, the back holes 15 to 18 being fired last. In Fig. 2a, the cut holes 1 to 6 are blasted together, followed by relievers 7 to 12 and finally by trimming holes 13 to 22. Fig. 3 shows arrangement with horizontal-bar mounting.

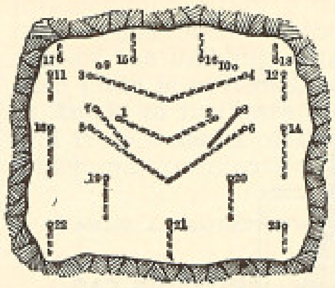


Fig. 3. Wedge-Cut Drilled from Horizontal Bar.

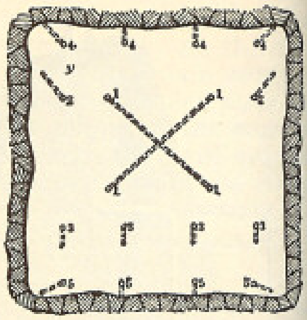


Fig. 3a. Pyramid Cut.

Holes 1 and 2 are "short-cut holes"; 3 to 6 are "long cuts"; 7, 8, 9, 10, 19 and 20 are "relievers"; 11 to 14 are "sides"; 15 to 18, "backs"; and 21 to 23, "lifters"; the numbers indicating the order of the blasting.

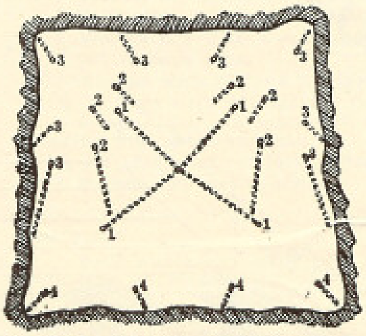


Fig. 4. Pyramid-Cut Round Drilled from Horizontal Bar.

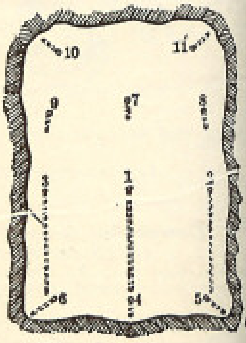


Fig. 4a. Bottom-Cut Round.

The pyramid cut consists usually of four holes drilled so that they actually or nearly meet at a common point (generally near the axis of the tunnel), which, when properly blasted, remove a more or less pyramidal core. Figs. 3a and 4 show two arrangements of this method. The numbers showing the sequence of the blasting.

The bottom or draw cut, Fig. 4a, is the method usually used for small tunnels and mine openings where it is impractical to drill an effective wedge or pyramid.

Depth of Hole

The most economical depth of hole must be determined by trial in each individual case, because of the numerous variables influencing the result. Usually a depth of round from 60% to 75% of the width of the working will be found satisfactory.

Number of Holes per Round

Physical character of the rock is the most important factor in determining the number of holes per round. In general igneous rocks require more holes than sedimentary rocks.

Arrangement of Drill Holes in Shaft Sinking

Drill-hole location in sinking is governed by the fact that only one free face is exposed, and that to obtain maximum efficiency from the charge two faces are necessary. One or more cut holes are drilled at an angle to the free face, and blasted in advance of the other holes, which are placed to take advantage of the new face formed by the blast. The cut is usually drilled at the middle of the shaft section, though in large shafts they are at times placed at one end, retreating towards the opposite end in blasting, and firing each row of holes in series. This arrangement tends to throw the broken rock to one end of the shaft so that the opposite end may be speedily cleared for the machines to begin work while mucking is in progress.

Hand-drilled holes are usually shorter and more numerous than machine-drilled; they are placed with care to take advantage of the bedding planes, cracks and shape of face, not with especial regard to the symmetry of the arrangement. The cut is sometimes carried well in advance of the other holes, which recede towards the shaft ends in a series of benches.

Machine-drilled holes are placed and pointed in accordance with a system designed to give desired results even at increased powder consumption. A symmetrical arrangement facilitates the operation of the drills, and enables the maximum number of holes to be drilled from each set up of the shaft bar.

"V," center or wedge cut is most commonly used. It comprises a number of pairs of holes inclined towards each other from opposite sides of the short

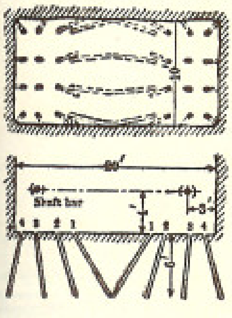


Fig. 5. "V," Center or Wedge Cut for Shaft Sinking

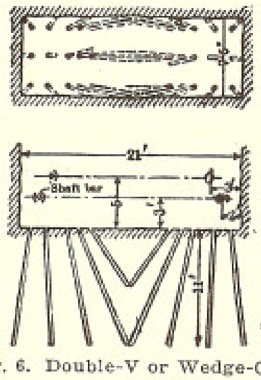


Fig. 6. Double-V or Wedge-Cut.

center line of the shaft, their bottoms being close together or preferably meeting. Figs. 5 and 6 show two forms of this cut. Holes in lines 1 comprise the cut and are blasted first. The other holes are blasted in sequence. Fig. 5 is a simple cut, while Fig. 6 is for a deep cut.

Pyramid cut is rarely used except in circular shafts. Figs. 7 and 8 show arrangement of this cut for round shaft and rectangular shaft, respectively.

The bench or stope cut (Fig. 9) is sometimes used in tight ground. The cut is alternated from one side of the shaft to another. There are always two more or less free faces, thus increasing the

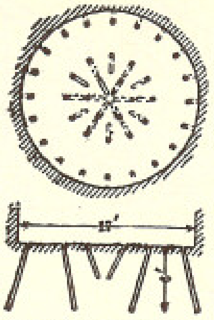


Fig. 7. Pyramid-Cut for Circular Shaft.

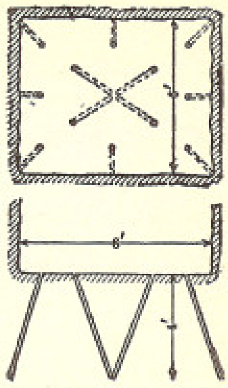


Fig. 8. Pyramid-Cut for Rectangular Shaft.

efficiency of blasting. This cut also tends to project the broken rock towards the opposite end of the shaft, as do the wedge and center cuts, so there is less delay in setting up drills and damage to timbers and pumps.

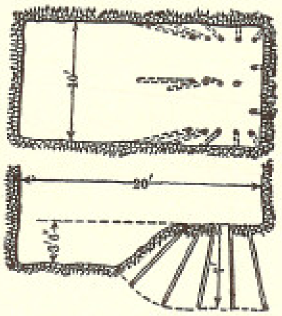


Fig. 9. Bench or Stope Cut.

Bottom cut (Fig. 10), similar to that used in tunnels, is sometimes useful for flat inclined shaft.

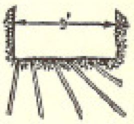


Fig. 10. Bottom-Cut for Flat Inclined Shaft.

ORDER FORM FOR LOADING MACHINE

1. Character of work, surface or underground...............
2. Kind of Material..
3. If approximately horizontal underground places, give height................ width...............
   If cylindrical tunnel, give diameter....................
   If shaft, give inside dimensions............Cage........
4. If material to be handled is in pitching formation, give angle measured from horizontal........................
   Thickness of seam.......................................
   Width of working place..................................
   Width of haulway floor..................................
5. Give maximum of size of lumps to be handled.............
6. Give amount of material that can be shot down and broken, at one time, ready for shoveling......................
7. Working places to dip or rise...........................
   What is the degree of dip or rise.......................
8. Working places wet or dry...............................
9. Power—Compressed air or steam...........................
   If air, number cubic feet available.....................
   Pressure........ If Steam, H. P........Pressure.........
10. Track gauge...............Size of rail...................
    Number of tracks and location in working places........
11. Car length.......width.......Height above top of rail....
12. Hand loading at present..................................
13. Name and address...
14. Name and location of operating plant.....................

SCRAPER MINING PRACTICE

This article is taken bodily from Mr. East's very able and complete article as published in the Mining Congress Journal of December, 1923. Mr. East gives credit to the following sources of information: Mr. Lucien Eaton, Mr. Ward Royce and Mr. F. E. Boyd, though articles appearing in Compressed Air Magazine, Mining & Scientific Press, Engineering and Mining Journal Press and Lake Superior Mining Institute.

The use of the scraper systems of mining and loading is a natural consequence of the increased cost of "mucking" or loading broken ore by hand which has been folowed for centuries.