BLASTER'S TRAINING MANUAL

For

Farmers, Ranchers, Prospectors, Engineers,

Small Construction Contractors

By

R.K. [Ken] House; U.E.L., I.S.E.E. [Retired]

Emeritus Member of International Society of Explosives Engineers 1998

A completely illustrated manual dealing with the responsible, safe, and effective use of explosives.

At the end of this Manual you will be able to determine the position and force of explosion required and select, assemble, plant and detonate electronically and non-electronically charges of industrial explosives, safely and according to the law.

Although this is a beginner's Manual, it will also upgrade the skills of people now working with explosives, as well as those who require a knowledge of the field: safety officers, supervisors, engineers, etc. This Manual will provide the basic skills and theory to assist in preparing for Provincial and State examinations.

Formerly

R.C.M.P. Contract Officer
Section “K”
October Crisis, 1970

Emeritus Member	**International Society of Explosives Engineers**	**1998**
Nominated:-	**Companion to the Order of Canada**	**1998**
Certificate of		
Nominated:	**Courage to Come Back Award [British Columbia]**	**1999**

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A completely illustrated manual dealing with the responsible, safe and effective use of explosives.

******DISCLAIMER******

Although the information herein is given in good faith and the methods discussed are based upon research and experience and are believed to be accurate.........

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The writer is an Internationally Accredited Professional Explosives Engineer who has worked in his profession for 36-years and who was a member of the Society of Explosives Engineers, International, from 1982 until his retirement due to health in 1991. Mr. House, also wrote/designed/taught the **"Commercial Explosives Course"** for **Pacific Vocational Institute Maple Ridge Campus**, **a Division of B.C.I.T. [British Columbia Institute of Technology]** This manual was originally written for the Dept. of National Defense, Ottawa, Ontario, Canada, after the CFB Chilliwack, BC, accident in June of 1988. It is now being offered in a re-write to the general public in its **Non-Military Form.**

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No warranty expressed or implied is given, nor do we assume liability for anything. Nor do we assume responsibility for what-ever purposes these manuals are used for or by whom. The Author.

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DEDICATION

This manual is dedicated to my loving wife, **Yana,** who has been a great inspiration to me over these last eight years and who would not allow me to forget about writing this manual, or leave it on the back burner, and who has tried very hard to keep me from burn-out, over the last 8-years while this manual was being written. And she has had to put up with my moods and frustrations when something I've been doing on the manual hasn't gone the way, I would like it to.

Thank you seems very in-adequate for what she has put up with so this manual is for her, and may she learn this;

He/She who attempts the ridiculous,

Can and will achieve the impossible,

Only to find out it was truth all, along.

A Special Dedication is to the late, Tibor Tchzmazia, Chief Mines Inspector, [D.I.A.N.D.], for the Federal Government in the Yukon Territory, who issued my first permanent blasting certificate, many years ago.

Tibor, passed away following open heart surgery early in 1979.

This manual is also dedicated to the memory of those Officer Cadets who lost their lives at, Canadian Forces Base, Chilliwack, British Columbia, Canada, in June 1988, due to the unsafe handling and usage of explosives, which they were being taught at that time.

It is the author's hope and prayer that this manual will eliminate the factors that led up to and caused the deaths of those men and one woman on that day in June, 1988.

KH

PREFACE

The purpose of this manual is to provide the average prospective user with a structured, understandable, illustrated manual in the handling and use of explosives.

To a large extent this manual is a compilation of data collected from many sources over the years, but never before brought together and organized into one volume. **Especially in Canada.**

No originality is claimed for much of the materials.

While the author hesitates to state that explosives usage can be mastered from the printed page, it is probable that safe and efficient blasting is 95% technical know-how which can be communicated efficiently to most persons through the printed word. In any event, it should be obvious that it would be exceedingly dangerous to follow the opposite route, and attempt to master explosives usage through trial-and-error in the field.

While every effort has been made to provide complete and detailed instruction, No Responsibility can be assumed for the reader who experiments with explosives. They are urged to do so initially ONLY under the guidance of an experienced Explosives Expert.

Chapter I

Introduction To Explosives

Tools are the great multipliers of man's energy and strength. And explosives are possibly the most versatile and hardest working of all tools. A few pounds of explosives releases more energy during its peak of detonation than the combined output of every electrical generator from coast to coast.

Like other modern tools and machinery, explosives replace hand-labor, save time and money, and perform tasks which would be impossible or impractical by other means.

Most modern machinery and equipment can only perform safely and efficiently under the control of a skilled operator. The same holds true for explosives. Explosives are safe, efficient and economical when used by persons who are trained in their use. But can be dangerous and costly in the hands of untrained persons.

Explosives have an important advantage over other tools and equipment which is often overlooked.....a power shovel can make excavations....a bulldozer can rip up stumps, boulders and foundations....and a crane can demolish buildings. But, these are extremely expensive pieces of equipment. On the other hand, explosives are not expensive, and it is not usually necessary to invest money in explosives stock as this can ordinarily be ordered as needed. Blasting accessories are also relatively inexpensive.

Mining, quarrying, construction, forest industry operations and agriculture are but a few examples of some industries which each use millions of pounds of explosives yearly.

It would be almost impossible to list all the present uses of commercial explosives. In property development alone, explosives are used for blasting rocks and boulders, buildings and cleaning irrigation and drainage ditches. Making and cleaning ponds and water holes, changing the course of streams. Removing ice and debris causing flooding. Removing stumps, subsoil blasting, digging fence and post-holes, tree planting and general construction and excavation.

About two billion pounds of explosives are used in the United States each year, and this amount is increasing at a steady rate.

The general public considers explosives highly dangerous. It is true that handling or using explosives without a thorough knowledge of the product and proper handling procedures is dangerous.....not only to the user, but possibly to other persons and property. However, explosives in the hands of a trained person, working with reasonable care and caution are no more dangerous than many other modern tools and techniques.

If you think about it, we handle and work around gasoline with little thought of danger, because we are familiar with it and take certain simple precautions. Yet gasoline is more sensitive and potentially more dangerous than commercial high explosives.

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ONE GALLON OF GASOLINE IS EQUIVALENT TO 28 STICKS OF DYNAMITE.

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That is not to suggest that the dangerous potential of explosives should ever be minimized or disregarded. It should always be kept in mind that these products are manufactured and intended to explode and cause damage.

On the matter of safety, it should be pointed out that much of the research and efforts of explosive manufacturers have been directed toward making their products safe to handle and use. **In accidents involving explosives, it is almost always found that the cause was human error. Some person was careless or ignorant in the storing, use or handling of the product.**

The rules for safe handling and use of explosives are simple to follow, and will be emphasized throughout this manual. The individual who knows and follows these rules and who works with reasonable care and common sense, is exposed to no more hazards than are found in many other industries and activities.

Notes:-

The History and Development of Explosives

About **1255 AD**, an English monk named **Roger Bacon**, wrote about **"Black Powder"** and gave directions for making it. He did not invent gunpowder. Some sources said the Chinese did so. Others say the Arabs or East Indians. But it was invented centuries before Bacon.

Early in the 13th century black powder was first used to propel stones from a gun, and from that time until the end of the 17th century it was used primarily in firearms.

The first recorded use of black powder for blasting was in Hungary in 1627. By 1689 it was being regularly used for blasting in the mines in England.

Black Powder manufacturing started in the United States in 1675 at Milton, Massachusetts. It may have been used in mines in the United States soon after 1712, but the first official record of blasting in the United States was in the construction of Negate prison in 1772.

Prior to 1831 methods of igniting charges of black powder for blasting were uncertain and dangerous. In that year, **William Bickford of England** invented the **"Safety Fuse"** which added much safety and certainty to blasting operations.

The formula for black powder had remained much the same over the years. **Approximately 75% Potassium Nitrate, 15% Willow Charcoal, and 10% Sulfur, by weight.**

In 1857 Lamont Du Pont replaced potassium nitrate in his black blasting powder with sodium nitrate, or Chile Saltpeter. This was much less expensive and greatly reduced the cost of black powder and led to its more widespread use in blasting.

"Smokeless Powder", called **GunCotton or Nitrocellulose**, **was discovered about 1838**, and by 1880 it had replaced black powder as the principle military propellant powder. It is NOT, however, suitable for blasting.

"Nitroglycerin", was discovered about 1846, but was unsuitable for blasting because of its extreme sensitivity.

Alfred Nobel of Sweden developed what we call **"Dynamite" in 1866**. He saturated porous earth called **"Kiesselguhr"** with nitroglycerin, which produced a solid substance which lacked the sensitivity of nitroglycerin yet could be exploded by a blasting cap, which he had previously invented.

Nobel's first dynamite was called "Guhr Dynamite" and was patented in 1867. **It was composed of 75% nitroglycerin and 25% Kiesselguhr**. In later years sugar cane and wood pulp were used as an absorbent in dynamite instead of the earth, resulting in a better explosive.

In 1875 Nobel made another discovery. **He dissolved a small amount of nitrocellulose in nitroglycerin, which resulted in a gelatin-like explosive more powerful than his dynamite. This led to the blasting gelatins and gelatin dynamites.**

The next important development was the use of **Ammonium Nitrate in dynamite**. This is a powerful explosive in itself and when mixed with other substances such as Nitroglycerin, Coal dust, Picric Acid, or Nitrobenzene, produced a cheap source of high explosive power.

In Ammonium Dynamite, a percentage of the nitroglycerin, Sodium Nitrate and Wood-Pulp is replaced by Ammonium Nitrate. This greatly reduces the cost and provides a more insensitive explosive with less shattering effect but more heaving power. This characteristic is useful in many kinds of commercial blasting.

More recently, blasting agents were developed. These are extremely economical, and very safe to handle and use because of their insensitive nature. The use of agents such as fertilizer grade ammonium nitrate mixed with various fuels gained widespread acceptance in the explosives industry.

Many Military explosives were developed and perfected during this period, including **TNT, Amatol, Picric Acid, RDX, PETN**, and many others. Most of these are suitable **"For MILITARY USE ONLY"**.

More recent developments include Water Gels, and explosives in Sheet Form, Two-part Liquids which become explosive when mixed together, and a wide variety of specialized products and packaging, cartridge forms and sizes.

Explosives and Explosions

There are Three Basic Types of Explosions

There are **Mechanical or Physics-Based** explosions, caused, for example, when the safety valve on a steam boiler sticks and the steam pressure builds up, eventually, the boiler will burst or explode. The are **Nuclear or Atomic** explosions, created when the Nucleus of an Atom is split.

And, there are **Chemical explosions**, which are what concerns us in this manual.

A chemical explosive is an unstable substance or mixture of substances which is capable of undergoing a sudden and violent decomposition or break-up. When it does, it produces an explosion through the great quantities of heat, energy and gas which are generated and released at very high speeds. **This pressure and heat in chemical explosions blows outward at about 9,000-miles-per-hour!**

Explosives are divided into three classes, depending to some extent upon the speed of their chemical reaction. **"Low Explosives** such as black powder and smokeless powder are relatively slow acting. They burn or **"Deflagrate"** rather than detonating as high explosives do. Black powder will simply burn rapidly if ignited in the open. But, ignite it confined in even a light cardboard container and it will explode. This chemical reaction in low explosives is easily initiated by a spark or flame.

The second class of explosives are the **"Primary Initiating High Explosives".**

These are High Energy Explosives which explode violently or **"Detonate"**. They are extremely sensitive to heat, friction and shock, and in very small quantities will explode with the violent shocking power needed to detonate main charges or the less sensitive high explosives. This is their principle use.

These are sometimes called **"Initiators" or "Detonators",** and are the explosives used in blasting caps. Examples of primary initiating explosives are **"Mercury Fulminate"** and **"Lead Azide"**. They are **easily initiated by flame, heat or shock.**

The third class of explosives are the **"High Explosives".**

High explosives explode violently, or **"Detonate".** But they are often relatively insensitive to heat, shock and friction. Unlike the primary initiating high explosives, many of these can be burned in small quantities without exploding, and can withstand considerable shock.

Main Charge High Explosives are most commonly exploded by **"Detonation",** that is, by a strong shock wave caused by the explosion of a primary charge comprised of the more sensitive primary initiating explosives. In other words, high explosives are generally exploded by an explosion.

Examples of explosives used as main charges in blasting are dynamite of the various types, blasting gelatins, TNT, etc.

NOTES:-

Explosive Firing Trains

You wouldn't try to light a large lump of coal using only a kitchen match. While the match produces flame and heat which are needed to light coal it doesn't produce sufficient heat to get the coal burning.

You would probably use the match to light some crumpled newspaper. The burning paper would provide sufficient heat to ignite kindling wood. The flame produced by the burning kindling would light the coal.

If this were especially hard coal, you might even have to introduce another step into this **"Train".** You might add some heavy stove-wood before the coal would burn.

The match is able to ignite the coal only indirectly, by starting a series of steps whereby the small amount of heat or energy produced by the match is finally built up to the much greater amount of heat needed to ignite the coal. This sequence of events.....the match lighting the paper.....the paper igniting the kindling, the kindling lighting the stove-wood and the stove-wood setting the coal on fire.....might be described as a **"Firing Train"**.

Explosives too, have a **"Firing Train"**.....a series of steps by which a small amount of initiating energy is progressively built up to the large amount of energy which is required to detonate a relatively insensitive main charge high explosive.

It is essential for the blaster to know the firing train needed to detonate the explosives he is working with. If he uses an inadequate firing train the charge may not detonate or may detonate incompletely and fail to develop its full power potential. This can be dangerous, as it can result in explosives being scattered about the area or left in the ground, where they could be exploded accidentally during operations which followed. At best, it will be extremely wasteful and costly in terms of wasted time.

As was mentioned earlier in this chapter, black powder is a low explosive, and as such can be readily ignited by a spark or flame. The spit of flame from a safety fuse is all that is needed to ignite a main charge of this low explosive. And, if large quantities are involved or if the charge is tightly contained or confined, it will produce a violent explosion.

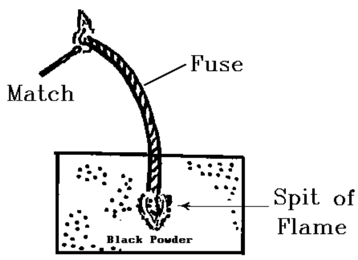

Fig. 1. "Initiating Black Powder Explosives".

Low explosives may be ignited in manners other than illustrated above, as will be described in later chapters.

To fire a cap-sensitive high explosive such as dynamite, another step must be added to the firing train. The flame from the fuse will not, in itself cause the dynamite to explode. A blasting cap must be added.

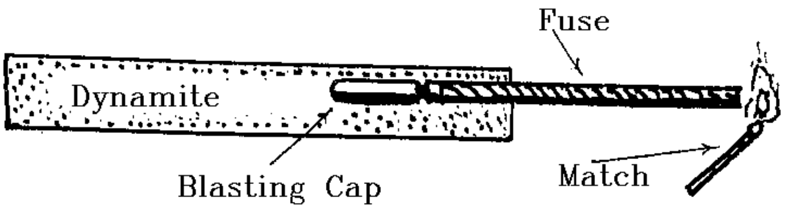

Fig. 2. "Initiating Cap-Sensitive High Explosives".

In the dynamite explosive firing train, the end-spit of the flame from the fuse enters the blasting cap and ignites flash-powders, which in turn detonate more powerful chemicals in the cap. These explode and provide the powerful shock needed to cause the dynamite to detonate.

Some high explosives are described as **"Cap-Insensitive"** because they cannot be reliably detonated by a standard commercial blasting cap. TNT is an example of such an explosive. An additional step must be added, in the form of a **"Booster"**.

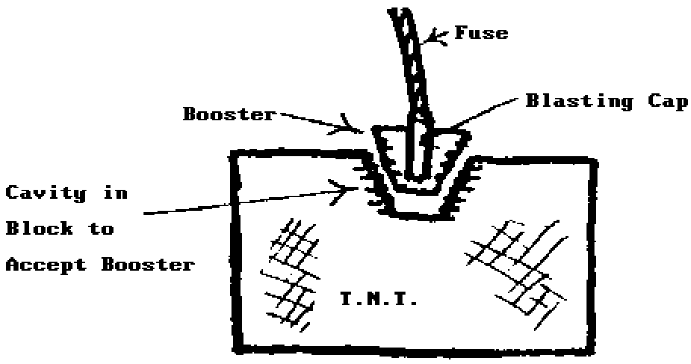

Fig. 3. "Initiating Cap-Sensitive High Explosives

The booster is a powerful primary-initiating or secondary high explosive which must be added in order to provide the great shock wave needed to detonate this relatively insensitive main charge high explosive.

Like the cap-insensitive high explosive, the blasting agent cannot be reliably detonated by a blasting cap alone. The cap simply cannot provide an initiating shock wave of sufficiently great strength to detonate the blasting agent. So, a booster or primer must be added to the blasting agent firing train. In the drawing a standard size dynamite cartridge has been added for this purpose.

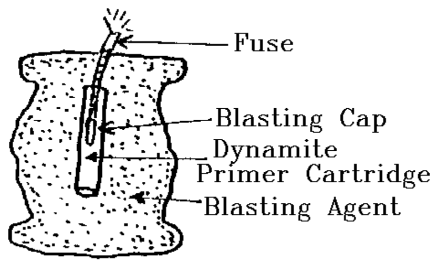

Fig. 4. "Initiating Blasting Agents".

In previous drawings we illustrated firing trains which employ a flame and safety fuse to ignite the action. Electrical methods of firing are commonly used in commercial blasting.

NOTES:-

Explosive devices are often fired by mechanical or chemical action. Below, we show an illustration of a firing train initiated by mechanical action.

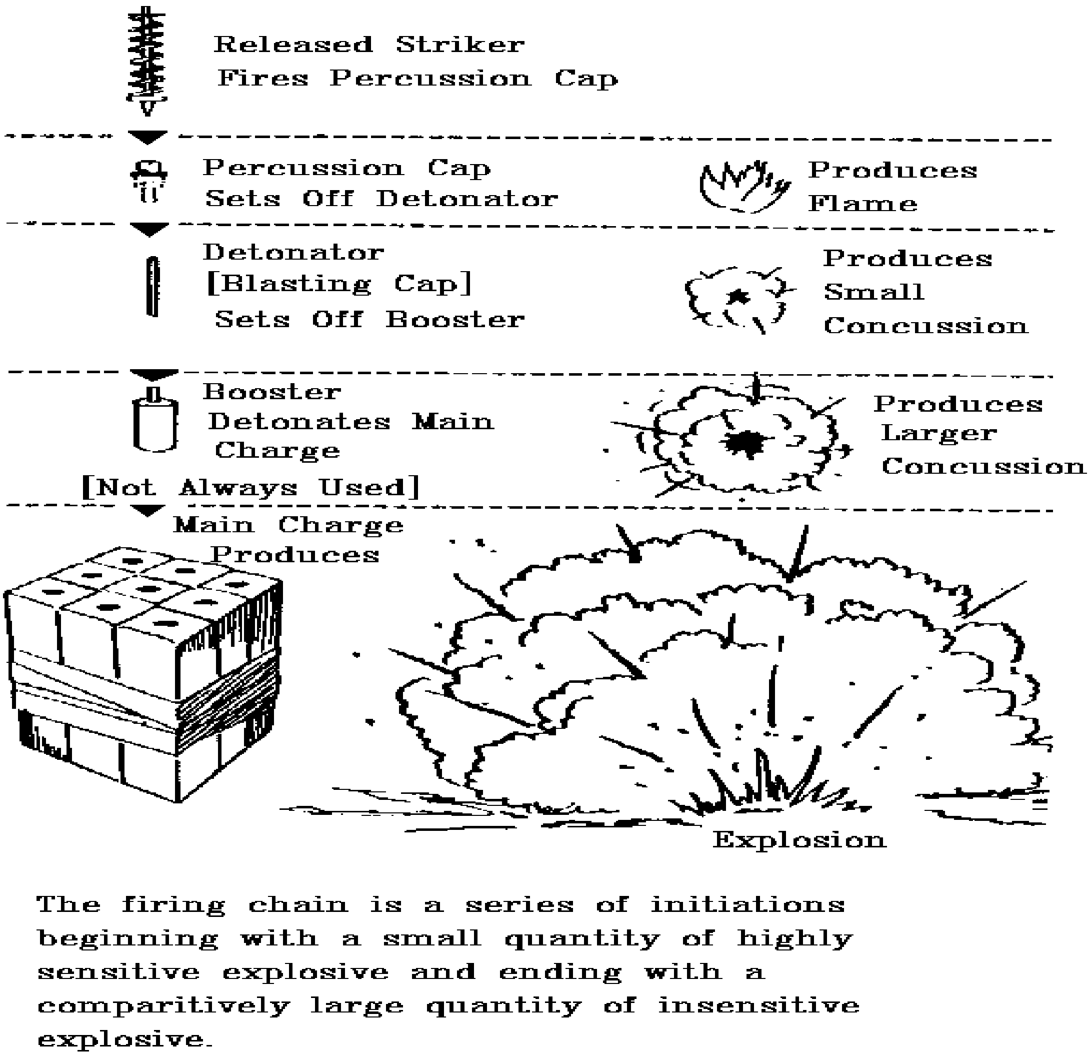

Fig. 5. "Firing Train".

Specific instructions for firing various types of explosives are contained in later chapters. The purpose of this discussion of firing trains is merely to aquaint the reader with the generalities and the fact that a suitable primer and firing train leading up to that primer, must be used to safely and reliably detonate high explosives.

Notes:-

Properties of Explosives

An explosive is a compound or mixture which, when it is initiated, undergoes a rapid chemical change which releases large amounts of heat and gas.

For a piece of wood to burn it must be ignited, and it must have oxygen.....which it draws from the air. For a fire, there must be fuel, oxygen and initiation.

A chemical explosion also requires fuel, oxygen, and initiation. However, an explosive must contain its own oxygen to be defined as an explosive. It cannot draw oxygen from the air as wood does when it burns.

Chemically, explosives may be divided into two broad classes, mechanical mixtures and chemical compounds.

In mechanical mixtures the combustible substances must be intimately mixed with some oxygen-supplying material as is the case with black powder, where carbon and sulfur are mixed with potassium nitrate. In that case, the charcoal is the fuel.....the sulfur is used to initiate or ignite the mixture and the potassium nitrate is the oxygen-supplying agent or oxidizer.

Nitroglycerin is an example of a chemical compound in which each molecule of the substance contains both the fuel and all the oxygen necessary to support an explosion.

Some explosives are mechanical mixtures of two or more explosive compounds. An example is gelatin dynamite, which is a mixture of nitroglycerin and nitrocellulose .....each of which is an explosive in its own right.

So much for chemistry! It isn't really necessary for a blaster to know the chemical make-up of the products he works with, or the chemistry of explosions. However, it is necessary for him to understand the fundamental effects of explosions. The general characteristics of various explosive products and the terms which are used to describe these characteristics or properties.

Explosives manufacturers offer a wide variety of products. There is an explosive suitable for every blasting need. But, the explosive which does a good job in removing stumps probably won't do a good job of shattering hard rock. The product used for shattering rock won't be satisfactory for lifting that rock out of the ground intact. Results and economy depend to a large measure upon selecting the right explosive for the job. Explosives manufacturers and dealers will be very helpful in suggesting a suitable product for a particular job, and giving sound advice. But, you should be able to **"Talk their Language"**, and have at least a general idea of what you need.

Let's examine the fundamental effects of an explosion. There is a blast, a pressure wave of compressed air moving outward at velocities of over a thousand feet per second and creating pressures as high as a million pounds per square inch. Also, heat and flame. **Temperatures of 3,000 to 4,000 degrees centigrade are not uncommon**. There is noise caused by the tremendous pressures of the gases which are released. There is fragmentation, materials will be broken and loose debris will move outward in every direction from the center of the blast. We have ground shock. A wave transmitted through the ground similar to an earthquake and capable of causing ground movement and disruption. There is suction.....a negative pressure wave following the blast wave. And finally, there are fumes principally carbon dioxide, nitrogen and steam, but also including poisonous gases such as carbon monoxide and nitrogen oxides.

So, the fundamental effects of an explosion are blast, heat, noise, fragmentation, ground shock, suction, and fumes. And, the nature and degree of each of these can be controlled by the blaster to some extent by the type of explosive product and the loading and firing techniques used.

Now is a good time to get rid of a common misconception. Some people will tell you that explosives exert most of their energy downward. Others say that explosives work upwards. Still others say that explosives work upwards. Still others say that explosives exert most of their energy against any object they are placed on or under. The fact is, the energy of an explosion is exerted equally in all directions.

Since explosives DO NOT direct their energy selectively it's up to the blaster to do this so to produce the results he wants. The blaster has the brains, NOT the explosive.

One of the skills of a blaster is his ability to determine the kind of explosive which will do the best job on any particular blasting project. Because of the many variables he may have to do some guesswork at first, and make a few "Test-shots". But, even in such cases he will be looking for certain characteristics in the explosives he test-fires. Obviously, he must have an understanding of the properties and characteristics of the most common types of commercial explosives. And, he must be familiar with the terms understood and used by explosive dealers and with manufacturers to describe the properties of their products. Accordingly, let's examine some of these terms and what they mean.

Velocity:- The term **"Velocity"** refers to the speed at which an explosive detonates. More exactly, it is the speed at which the detonating wave travels through the explosive.

The velocity of explosives is usually expressed in **"Thousands of feet per second"**. If you took an explosive which had a velocity of 10,000-feet-per-second.....and packed it into a column which was 1 1/4 inches in diameter and 10,000 feet long.....this mythical cartridge would detonate throughout its entire 10,000 foot length in one second.

Dynamites are available in a wide range of velocities, from about 4,000 feet per second to over 20,000 feet per second. Some explosives have velocities as high as about 30,000 feet per second.

The velocity of an explosive is a rough measure of the shattering ability of that explosive. Generally speaking, the higher velocity explosives produce sharper detonations with more **"Shattering"** action. The lower the velocity the more **"Heaving or Lifting"** action an explosive will have.

Let's assume you have a boulder half-buried in soil. Under some circumstances you may wish to shatter this into smaller pieces. In such a case you would select a higher velocity explosive. To fragment formations of rock, an explosive with a velocity of at least 12,000 feet per second is usually required.

On the other hand, perhaps you just want to lift this boulder out of the ground.....more or less intact.....so you can haul it away. In this case you would use one of the lower velocity explosives which cause less fragmentation but exerts a powerful lifting action.

Again speaking generally.....because there are other factors involved.....the high velocity explosives are used where a fast, shattering, fragmenting or cutting action is desired.....and the lower velocity products where objects or large quantities of loose materials are to be moved or lifted without the need of extensive fragmentation.

Strength:- **"Strength** refers to the energy content of an explosive. It is a measure of the power and force it will develop.

Strength should not be confused with velocity, since we can have a strong or powerful explosive which is comparatively slow-acting.

The strength-rating of **"Nitroglycerin Dynamite"** is based upon the percentage of nitroglycerin it contains, by weight.

A 40% straight nitroglycerin dynamite contains 40% nitroglycerin by weight.....a 60% straight dynamite contains 60% nitroglycerin.....and so forth.

A common mistake is to assume for example, that a 60% dynamite has twice the strength of a 30% dynamite. This is not true Just because the cartridge contains twice as much nitroglycerin doesn't mean it is twice as strong, because ingredients other than nitroglycerin also contribute to the total strength of the explosion. When the amount of nitroglycerin is reduced, this is replaced by other energy producing materials. While these don't contribute as much energy as the nitroglycerin, they replace they do contribute some.

Not all dynamites have nitroglycerin as the main energy producing ingredient. Yet the **"Strength"** of these other types is also expressed as a percentage. But, in such dynamites the percentage strength does not refer to the percentage of nitroglycerin they contain, but rather their strength compared to nitroglycerin or straight dynamite.

In other words, explosive strength is generally rated either by the percentage of nitroglycerin.....or equivalent in explosive power.....contained in an explosive. So, a 60% strength ammonia dynamite doesn't contain 60% nitroglycerin, but this dynamite has the same strength as 60% nitroglycerin dynamite.

And a 40% weight-strength ammonia dynamite does not contain 40% nitroglycerin, but on the weight-for-weight basis it has the same strength as a 40% N.G. dynamite.

Up to this point we have been discussing **"Weight Strength"**. Explosives are occasionally rated by what is called **"Volume Strength"**, or **"Cartridge Strength"**. When you see a dynamite so graded this indicates that one cartridge of that dynamite has the same strength as one cartridge of the same size of nitroglycerin dynamite similarly marked. One cartridge of ammonia or **"Extra"** dynamite marked 40% bulk-strength has the same strength as one cartridge of 40% nitroglycerin dynamite, even though they may not weigh the same.

In our judgment, **"Bulk-Strength"** is a more useful measure in commercial blasting, because a loading crew can more easily load a certain number of cartridges into a borehole than a certain number of pounds.

Summarizing, **"Strength"** is the ability of the explosive to do work, and is dependent upon the volume of gas which is liberated during the explosion. The time needed for an explosive to develop its maximum pressure is not taken into account when determining its strength, but this time factor.....or the explosive's velocity greatly effects its shattering ability and the violence of the detonation.

Density:-   Explosives are available in a wide range of density. The term **"Density"** generally refers to the weight of an object when compared with the weight of the same volume of water.

What does **"Density"** mean to the blaster? Why should this interest or concern him? Well, by having a wide range of densities available the blaster can concentrate or distribute charges so as to best serve his purpose.

For example, in driving tunnels and other work in hard rock it is usually necessary to concentrate as much explosive energy as possible in each foot of drill hole. Since the costs of drilling in hard rock exceeds the cost of explosives per cubic yard of excavation, it is usually desirable to pack as many pounds of explosives as is possible in every foot of borehole. Therefore, a powerful and highly dense explosive is called for.

On the other hand, when working with softer materials it is often desirable to **"String-Out"** the explosive power throughout a long borehole. You don't need a heavy concentrate of power, and a low density grade explosive would be called for.

Or you may wish to load explosives of different densities in the same hole. For example, the job may call for a concentration of power at the bottom of the hole where the explosive has a lot of work to do.....but less concentration of energy is needed closer to the surface. In such cases you may load high density explosives at the bottom of the hole and fill the remainder of the hole with a low density, **"Bulky"** grade explosive.

Explosive manufacturers make it easy for us to get an idea of the density of their cartridged explosives, by indicating the number of 1 1/4 by 8 inch cartridges contained in a 50-pound case. We use this as a simple means of comparing the density of various products.

The number of 1 1/4 X 8-inch cartridges in a 50-pound carton varies from about 85 to 205. Obviously then, some cartridges weigh almost two and one-half times as much as other cartridges of the same size.

The product having 85 cartridges to a 50-pound case would be called a dense or **"Low-Count"** dynamite.....low count referring to the relatively low number of cartridges in the case.

The product having 205 cartridges would be called a low-density or **"Bulky"** explosive, and may be referred to as a **"High-Count"** dynamite, again referring to the high number of cartridges in the case.

Dynamite with a cartridge count of 140 has a weight approximately equal to the weight of water.

Generally speaking, the denser the mass of the charge the more effective it will be up to a point. For every explosive there is an optimum density.

Explosives are manufactured in many graduations of strength, velocity and density, to meet the needs of all kinds of blasting work. In practical use, speed, strength and density need to be balanced for the particular job at hand.

Water Resistance:- The water resistance of commercial explosives varies widely. Some can withstand long exposure to water. Others will lose their efficiency quickly and become desensitized if exposed to water.

If you are engaged in a blasting project where water will not be a problem, then you need not concern yourself with this factor in selecting explosives. However, if water is likely to be encountered you should chose your explosives with this in mind, and select a product having the degree of water resistance which will be necessary.

If blasts are to be fired in wet holes within a few minutes of being loaded, then an explosive with slight water resistance will do. If charges will be fired in wet holes fairly soon after loading, an explosive with medium water resistance will be adequate. However, if the charge will be left underwater for any appreciable length of time an explosive with good or excellent water resistance should be used.

Generally speaking, gelatin dynamites have the best water resistance of commercial explosives. High density nitroglycerin dynamites have good water resistance, while most lower density ammonia dynamites have little or no water resistance.

In some instances explosives which have little or no water resistance may be obtained in waterproof containers. If used in wet work, such products must be handled carefully to ensure that the container remains intact.

Fumes:- All commercial explosives produce gases when they detonate. These are principally carbon dioxide and nitrogen which are not toxic. However, explosives also produce varying qualities of poisonous gases which we call **"Fumes"**.

Exposure to carbon monoxide or nitrogen oxides found in **"Fumes" CAN BE FATAL!** Even non-fatal concentrations can cause permanent damage. Fumes may be hazardous to the blaster and others in the area, and at best their presence in an area prevents future work until they have cleared.

The nature and amount of poisonous fumes produced by a detonation varies greatly with the type and grade of explosive involved. So, this is another property the blaster may have to consider when he is selecting his explosives. Obviously, the problem of fumes will be extremely important in mines or other confined spaces. On the other hand, fume quantities may be of little or no concern in shooting in the open where fumes will disappear rapidly.

Any explosive used underground or in poorly ventilated areas should preferably carry a **"Fume Class I" rating**. **This means that it produces less than 0.16 cubic feet of toxic gases per 1 1/4 X 8-inch**

cartridge. Explosives having fume classes 2 or 3 may be used in confined areas where there is better ventilation.

A blaster must consider fume dangers when selecting his explosives, and would naturally select an explosive with good fume properties in cases where fumes could be a hazard. And, he should keep in mind that regardless of how good the fume characteristics of the explosive he is using are, dangerous fumes will still be produced and under no circumstances should personnel re-enter the blast area until all smoke and fumes have disappeared!

Resistance to freezing:- Frozen dynamite is extremely dangerous to handle and use. Fortunately, dynamite which is manufactured and sold for use in this country has had freezing depressants added, and will not freeze under ordinary exposure to the lowest atmospheric temperatures expected in North America. However, it is always possible that through some strange coincidence you may encounter frozen dynamite. **If you do, DON'T HANDLE IT! Contact your explosives dealer or manufacturer.**

Sensitiveness and Sensitivity:- "Sensitiveness" refers to the propagating ability of an explosive, And **"Sensitivity"** to the ease with which it can be initiated.

Explosives must have a sufficient degree of sensitiveness to ensure the complete detonation of all cartridges throughout the entire charge. In other words, the detonating wave must be initiate all the explosives in the charge at their intended velocity, and this obviously requires a degree of sensitiveness. On the other hand, commercial explosives must not be so sensitive that they will be exceptionally dangerous to handle and use.

A commercial explosive should be easy to detonate by specific methods, but difficult or impossible to set-off accidentally with normal careful handling.

The Importance of Confining Explosives

In a gasoline engine, the gas is confined in the cylinder when fired, so that its released energy is directed toward driving the piston. The energy of the gasoline is carefully harnessed and directed.

The energy of an explosive must also be carefully harnessed and directed if it is to do the work expected of it. Firing an unconfined explosive is like operating an engine with a hole burned through the piston.....much of the energy will be wasted.

It is the sudden tremendously high pressures which are generated by detonating explosives which provide the energy to do the work. The efficiency and economy of explosives usage depends to a large extent upon how well these pressures are controlled and directed.

Confinement also helps the reacted or detonating explosives to detonate the unreacted explosives. Some less sensitive explosives and blasting agents will not propagate or fire properly unless they are well confined.

To illustrate the importance of confining explosives in the interests of efficiency and economy, let's consider a simple boulder-blasting job performed in two different ways. The boulder in question is three feet in diameter.

In the first case, we drill a hole into the center of the rock and tightly pack and stem our charge. This is called **"Blockholing"**, and about one-half cartridge of a suitable dynamite will likely break up the rock.

In the second case, we place our explosives directly on top of the rock, and cover them with a heavy mound of mud. This is called **"Mudcapping",** and it will take 4 - 5 cartridges of the same explosive to break the rock by this method.

From these two examples it will be seen that eight to ten times as much explosives were needed to break the rock with an external, poorly confined charge.

Good confinement isn't always possible. For example, you may be blasting in very light, loose material. Or, you may not have any drilling equipment on hand. Or, you may be blasting fractured or seamy rock. Or, you may be forced to use external charges for such jobs as cutting steel plate or beams. But, good confinement is something we usually attempt to achieve whenever we can, and which is absolutely necessary when working with some explosives.

Where good confinement is impossible, we can often compensate to some extent by using high velocity explosives.

<u>Chapter II</u>

The Non-Electric Firing of Explosives

We will now describe the components, tools and techniques used in the preparation and firing of non-electric explosive charges.

Fuse methods of firing are usually used in agricultural and smaller blasting jobs, and in secondary blasting. The methods is particularly suitable for firing one or more independent charges with a minimum of equipment and preparation.

In the usual non-electric firing train, a length of safety fuse is inserted into the open end of a fuse blasting cap and crimped. This length of safety fuse to which a blasting cap is attached is called a **"Fuse Primer".**

When this **"fuse primer"** is inserted into a cartridge of dynamite and tied or taped so as to hold it in place, it becomes a **"Primer Cartridge".**

A primer cartridge.....sometimes called just a "Primer" is simply a properly assembled combination of fuse, cap and an explosive cartridge. Usually only one such primer is used to initiate one charge of explosives. Regardless of how great a quantity of explosives is involved.

The safety fuse is ignited.....burns throughout its length.....sets off the blasting cap.....the cap detonates the dynamite primer cartridge.....and this detonates all the other explosives in the main charge.

This doesn't sound complicated and it isn't! However, there are a number of components involved and many techniques which you should understand and carefully follow. You will surely wish to understand the workings of each in your firing train and how each of these must be handled and used.

<u>NOTES:-</u>

Safety Fuse

Safety fuse was invented by, **William Bickford of England in 1831**, and is still manufactured by the **Ensign-Bickford Company of Simbury, Connecticut.**

Safety fuse is a product used to convey an enclosed flame to an explosive charge, at a more-or-less uniform and predictable rate of speed. It may be used to fire a charge directly.....as in the case of a low explosive.....but more often does so indirectly by igniting a blasting cap which in turn detonates the main charge.

Safety fuse contains a train or core of special high quality black powder which is tightly wrapped in several covering layers of various textiles, waterproofing and other materials.

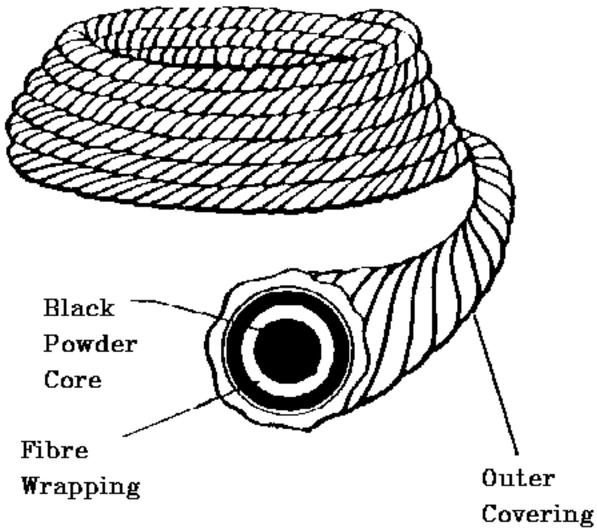

Fig. 6 Cross Section of Safety Fuse.

The coverings on safety fuse serve three important purposes. First they protect the core from abrasion, penetration and other damage. Second, they protect the powder from water and dampness. And third they confine the burning fuse from igniting nearby flammable objects and explosives.

Fuse with a burning speed of approximately 120 seconds per yard.....or 40 seconds per foot.....is considered **"Standard"** in this country, although fuse can be purchased with a speed of 90 seconds per yard.....or 30 seconds per foot.

Regardless of the advertised burning rate of fuse it should be emphasized that these are approximate speeds only!

A number of variable factors over which the manufacturer has no control influence the actual burning rate of fuse in the field, including the manner in which it is stored, the altitude, the weather, and the tightness with which it is confined in a drillhole. Generally speaking, the greater the confinement or pressure upon safety fuse the faster it will burn.

Most careful blasters test their fuse before making up fuse primers by burning a section and timing it. **Fuse rated to burn at 40 seconds per foot should be discarded if it test-burns in less than 36 seconds per foot or more than 47 seconds per foot. Use only fuse which you have positively identified and test-timed!**

Also, some blasters consider the burning rate of standard fuse at 2 feet per minute when making their calculations. This gives them an extra 10 seconds per foot as a safety margin.

It is extremely important that safety fuse be stored in a dry place with adequate air circulation to prevent condensation. Humidity will quickly damage fuse. The powder core absorbs moisture readily.....especially at the cut ends.....and this can alter or kill the ignition.

Fuse must also be protected from excessive heat, which softens the waterproofing. It should not be stored in a hot magazine or near stoves, steam pipes, boilers or other sources of heat. It must also be kept in mind that the black powder core, can be readily ignited by spark, flame or a hot surface.

Low temperatures do not usually harm safety fuse permanently, but cold will cause it to become hard and brittle and it should not be uncoiled or used while in this condition. **Store it at room temperature until its pliability has been restored.**

Care should be taken to avoid coiling fuse into small diameter coils or otherwise kinking or shape bending it. This can break the powder train and cause misfires.

Oils, paints, kerosene, gasoline or other solvents should never be stored or used near fuse.

Because of the possibility of fuse being damaged or exposed to dampness during storage.....or becoming brittle with age.....stocks of fuse should be stored and rotated so as to ensure that older fuse is used first.

Non-Electric Blasting Caps

There are two types of blasting caps.....electric caps and non-electric or fuse blasting caps. The former are initiated by an electrical current.....**the latter by a burning time fuse.**

Fuse or non-electric blasting caps convert the burning **"End-Spit"** of flame from a length of safety fuse into a detonation. In other words the caps changes a small flame into an explosion of sufficient magnitude to detonate most high explosives.

The standard blasting cap, sometimes called a **"Number 6 Cap"**.....is an aluminum capsule one and three eighths inches long. Open at one end and closed at the other. It is about the same diameter as a lead pencil, and the open end will accept safety fuse. The fuse is inserted seven-eighths of an inch before it contacts the detonating mixture.

Blasting caps are not simply filled with one kind of explosive. They usually contain three different charges. First, and nearest the fuse is an ignition charge.....sometimes called a **"Flash Charge"**. Next comes the **"Priming Charge"**, which is a very sensitive primary-initiating high explosive. And finally there is the **"Base Charge"**, which is a powerful secondary high explosive which detonates very briskly and provides the shock waves needed to detonate a cap-sensitive main charge of high explosives.

The **"Igniter** or **"Flash Charge** is often a high grade of black powder.....the **"Priming Charge"**, often lead Azide.....and the **"Base Charge"   TETRYL, PETN, or R.D.X.**

The fire-sensitive ignition charge is ignited by the spit of flame from the inserted fuse.....causing burning. The primer charge converts this into a detonation. And this detonation initiates a secondary high explosive base charge.

Blasting caps contain highly sensitive and extremely powerful explosives and are sensitive to heat, shock and friction. Obviously, they should always be handled with extreme care!

Blasting caps are packed horizontally in cartons of one hundred. **Never store or place them open-end up, or otherwise expose them to foreign matter. At best, this could cause a misfire. At worst it could cause the cap to explode accidentally!**

And, NEVER, EVER.....try to take a blasting cap apart, mutilate it, or insert anything in the open end except a safety fuse!

Also, blasting caps should never be stored with explosives, or transported in close proximity in the same vehicle.....for obvious reasons.

Below we illustrate a fuse-type or non-electric blasting cap.

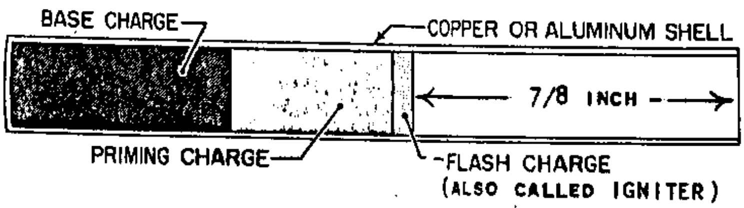

Fig. 7. Non-Electric Blasting Cap.

Determining Fuse Length

Nothing we say regarding fuse length should take precedence over any legal requirements in your own area. Some countries stipulate the minimum lengths of fuse which may be used.

<u>**"IN CANADA, THE MINIMUM LENGTH IS 6 FEET."**</u>

Also, you cannot purchase fuse in Canada, with which you attach the blasting cap. The law now requires that the explosives dealer supply "Fuse Length Assemblies" already made up at the dealers or by the manufacturer.

In fact one community we know of even prohibits the use of fuse altogether. Learn the regulations in your own area or province and follow these.

Regardless of the depth of a **"Borehole**, the length of fuse used should always be long enough to reach from the primer cartridge to well outside the mouth of the hole**. Under no circumstances should the fuse extend less than 24" from the collar of a shothole. Some regulations prohibit the use of any length of fuse less than thirty inches.**

Make it a practice to never cut any lengths of fuse less than six feet long.....and never have less than thirty inches of fuse extending from the collar of the shothole! Remember, "A little more fuse adds a lot more safety".

In determining the fuse length beyond the recommendations already spelled out, you must obviously consider the time it will take you to walk to a previously selected place of safety after lighting the fuse. And, if you are going to be lighting more than one fuse before leaving the blast area, **you must add the length of time it will take you to light the entire "Round" allowing yourself a healthy safety margin.**

If you are lighting numerous fuses at one time, you are strongly advised to use **"Igniter Cord" or "Hot-Wire Fuse Lighters"**, which are described in a later chapter.

And as previously suggested in making your calculations for fuse lengths figure the burning rate of standard fuse at 30 seconds per foot instead of 40 seconds and this will give you an extra margin of safety. Fuse is cheap and it is much better to use a little more fuse.....and wait a few seconds longer for the blast than to expose yourself and others to unnecessary danger!

After loading the charge you can probably use a little rest anyway.....or perhaps a smoke.....so why don't you use extra fuse and have your rest or smoke in a protected place while waiting for the blast?

Here is a formula for determining the length of fuse which will fire a cap in a fairly precise period of time.

A] Test-burn and time a six-foot length of fuse;

B] Divide the time between the ignition-spit and the end-spit by six to give average burning rate per foot;

C] Divide the desired time of fuse [in seconds] by the burning rate per foot [in seconds] to arrive at the length of fuse needed [in feet and tenths];

D] Convert the tenths of feet into inches by multiplying by 12. This gives you fuse-length in feet and inches.

Example:- Suppose you wish to cut a length of fuse which will detonate a charge in 5 minutes or 300 seconds. Test burn exactly six feet. Suppose the time consumed is 270 seconds.

Divide 270 by six to be obtain the average burning rate of 45 seconds per foot. Divide into inches by multiplying by 12, which gives you 7.9 inches.

Your answer is 6 foot 7.9 inches, so you'd probably cut your fuse 6' 8" in length.

Making Fuse Primers

Fuse primers are trimmed lengths of safety fuse to which a fuse blasting cap has been attached.

The operation of making fuse primers is simply cutting and capping fuse lengths.....which is relatively simple. **However, this is one of the most important jobs in blasting, because it must be done with great care and attention to detail. Errors or sloppiness can have serious results!**

First, examine the piece of fuse. If the protective coatings appear to have been damaged.....discard it. If it appears to have deteriorated.....discard it. Fuse is cheap and misfires are costly and dangerous.

Then cut at least one inch from both ends of the length of fuse you have selected. The black powder core rapidly absorbs moisture through the fuse-ends and we minimize the chances of this causing us trouble by trimming off the ends.

Care must be taken in cutting safety fuse. Preferably it should be cut with the cutting portion of the cap-crimper tool. If you are using a knife it should be clean, dry and very sharp. The fuse should be placed across a flat surface so it is at no time sharply bent, and the cuts should be Slanting cuts prevent proper seating of the fuse in the cap. **If a cut is not square, don't settle for it.....cut it again.**

Under no circumstances should you cut fuse with shears or wire cutters. This will often squeeze the fuse out-of-round.....distorting the power train and making for difficult insertion of the fuse into the cap.

After you have made the cut, examine the cut end closely. Sometimes the waterproofing compounds in the fuse become sheared over the powder core.....especially if the fuse is very warm or the knife is dull or dirty. This will prevent proper ignition.

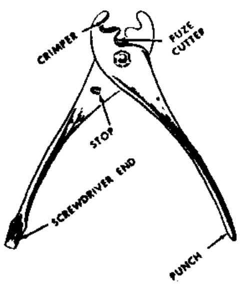

FIG. 8. CAP CRIMPERS

Sometimes, fuse is flattened or crushed out-of-round when cut. This makes it difficult to insert into the cap. When this happens, simply roll the ends of the fuse back and forth between the palms of your hands a few times and it should return to its proper shape.

For cutting and capping fuse you need a cutting-crimping tool, usually called **"Cap Crimpers"**. Explosive suppliers stock these and they are inexpensive. They resemble a pair of pliers and consist of specially shaped cutting jaws to cut fuse, and crimping jaws to secure blasting caps to safety fuse. Like other tools which come into contact with explosives, these are made of a non-sparking metal generally brass or a silver type aluminum-pot-metal alloy.

See diagram on next page.

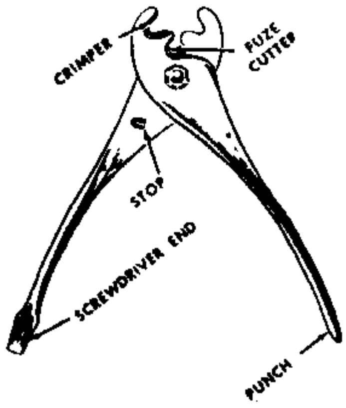

FIG. 8. CAP CRIMPERS

Never use for cutting wire or other hard objects. The non-sparking material of which they are made is not very hard, and they will lose their edge quickly if they are abused. Crimpers should be used for cutting fuse, crimping caps and punching dynamite cartridges.....ONLY!

After cutting the fuse, the next step is to insert it into the blasting cap. First, examine the end of the fuse to be sure it has been cut squarely and the powder core has not been smeared with waterproofing. Then examine the cap to make sure there is no foreign matter in it.

If caps have been stored on their side in the original container, foreign matter should not have had an opportunity to enter. But, it is a good practice to turn caps open-end-down and shake them before using. However, NEVER TAP a blasting cap against a hard object or with a hard object and never blow into the open end of the cap, as this may dampen the igniter charge.

Insert the fuse end into the cap. When you do, don't twist or screw it in. Push it straight in without any twisting motion and without using unreasonable pressure.

Be sure the fuse end is seated against the detonating compound in the cap. Until you become familiar with the "FEEL" of this you may wish to mark or hold the fuse seven-eight's of an inch from the end, and continue to insert the fuse until this amount has entered the cap.

If the fuse is not seated directly against the cap compound because of either a slanting cut, foreign matter in the cap or the fuse not being fully inserted.....then the cap is likely to misfire.

Next, we crimp the cap onto the fuse making sure the fuse is fully inserted. We hold it near the end in one hand and using the index finger of that hand we apply pressure on the end of the cap. With the crimping tool in the other hand we crimp the cap firmly against the fuse. The crimp should be from one eighth of an inch to not more than one quarter of an inch from the open end of the cap. **Keep in mind that the cap is filled with sensitive explosives!**

Test the crimp to be certain that cap and fuse are firmly attached and won't pull apart under normal strains. Loose crimping can result in the fuse and cap becoming separated under the stress of loading and tamping, and this can cause a misfire and the explosives in the charge to burn. On the other hand, the crimp should not be so firm as to deeply crush or distort the powder core in the fuse.

When crimping , point the base of the cap away from yourself and hold the cap and crimpers with your arms in an extended position.

When working in wet holes it is a good idea to put a second crimp in the cap. Rotate the cap about a quarter of a turn. Drop the crimping tool another eighth of an inch or so down the cap and crimp it again. This should be quite waterproof. However you are advised against using non-electric caps in charges which will be underwater for any appreciable period of time.

Cap sealing compounds are sometimes used to moisture-proof the connection between a non-electric cap and safety fuse in addition to the double crimp. The most suitable is a quick-drying, viscose, rubber-based sealer. Rubber cement and paraffin wax may be substituted in an emergency.

Make up only a sufficient number of primers for one day's operation. If you must keep them longer, lay them on a flat surface. Do not hang them on a nail or peg as is often seen. And, protect them from dampness and heat.

For large operations, a bench type cap-crimper is available which cuts fuse squarely and double-crimps caps semi-automatically with great speed.

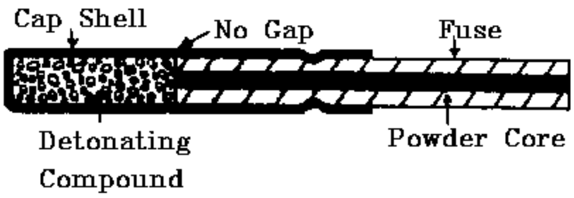

Fig. 9. Non-Electric Blasting Cap & Fuse.

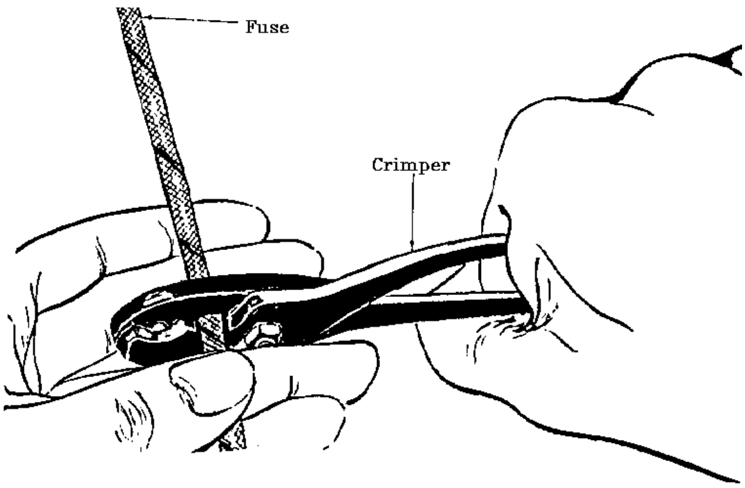

Fig. 10 Cutting Fuse

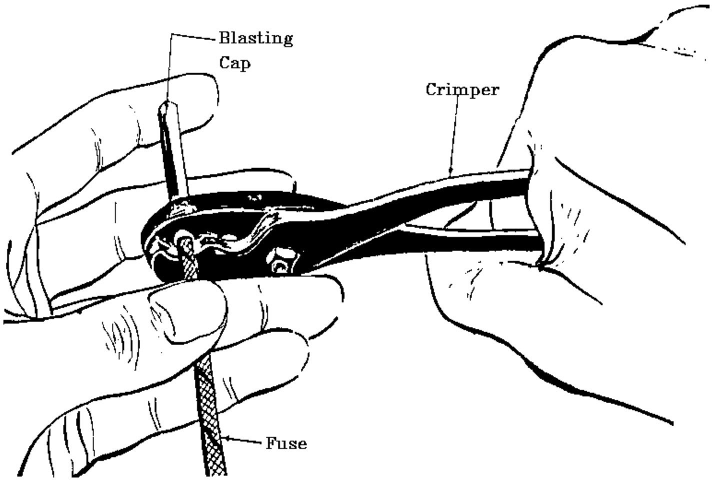

Fig. 11. Crimping Cap On Fuse

Notes:-

Dynamite Primer Cartridges

The final component in the dynamite firing train is the **"Primer Cartridge"**. A main charge of dynamite is usually exploded by one dynamite cartridge into which a blasting cap has been inserted and which is properly positioned and detonated in the main charge or column.

This is called a **"Dynamite Primer Cartridge"** or more often simply a **"Primer"**. Its job is to detonate the entire main charge. It is called the **"Spark Plug"**.

Later in this chapter we will describe and illustrate in detail how to make recommended primer cartridges for firing with cap and fuse, and in later chapters we will show how to make primer cartridges for electrical and detonating cord firing. But, for the moment let's consider the general considerations in primer cartridge fabrication.

When making up primer cartridges, keep in mind that you have in your hands a combination of a sensitive blasting cap, plus a cartridge of powerful high explosives which that cap can detonate! **This combination is potentially far more dangerous than either of the two components handled separately.**

Primer cartridges should only be made up as needed, at the blast site. They should not be assembled at powder magazines or close to cartons of explosives or other workers. Primers should not be assembled in advance and then stored or transported.

When making up primers, use only proven methods. Don't experiment. Pay careful attention to what you are doing, as this is a job that requires your undivided attention.

Primers must be assembled so the blasting cap is completely imbedded into the explosive.....approximately in the center of the cartridge.....with the cap pointing more or less lengthwise down the cartridge. There are several reasons for completely imbedding the cap in the explosive.....by far the most important being to protect the sensitive cap from abrasion and shock during loading.

Never force a blasting cap into position in the dynamite. Always punch a hole into the cartridge first, using the handle of your cap-crimpers or a dynamite punch. A punch can be improvised from a piece of hardwood dowel.

When you are punching a slanting hole into dynamite, as is called for in certain types of primers, be careful not to punch all the way through the cartridge. This has allowed caps to be forced completely through the cartridge during loading.....exposing the cap to shock and abrasion.....and resulting in premature, fatal explosions. Fuses or wires must be attached to the cartridge in such a manner that the cap will not be pulled from the cartridge if any reasonable strain is placed upon the fuse or wires.

Fuse and wires should also be tied or taped & held to the cartridge in such a position that they will not be subjected to sharp kinking or abrasion when the cartridge is loaded into the borehole.

It is common practice to slit the wrappers or covers on dynamite cartridges so the explosives can be **"Tamped"** or tightly packed into the borehole. **However, under no circumstances should you ever slit or mutilate the wrapper or shell of a primer cartridge! Such a practice can cause the cap to become forced from the protection of the cartridge during loading.**

It is the base of the blasting cap which explodes with the greatest violence, and the maximum shock wave travels down the primer cartridge in the direction the base of the cap is pointing. Therefore, the method of priming which is selected should be such that when the primer is positioned in the charge, the base of the cap will be pointing toward the main charge of explosives.

If wet conditions are likely to be encountered, the primer should be made of water resistant grade of explosive and all components water resistant or water-proofed. If prolonged submersion is anticipated, electric or detonating cord firing systems should be selected in preference to cap and fuse firing.

Preparing Fuse Primer Cartridges

Small diameter fuse primer cartridges should be made in one of four different ways. These all meet the general requirements and have proved to be safe and practical over many years in the field.

There is **"Side Priming"**....."**Top End Priming" [which is also known as Top Center Priming]....."Laced Fuse Priming"**.....and **"Bottom Center Priming"**, which is also known as **"Reverse End Priming".**

The choice of priming method is sometimes a matter of personal preference, but it is often dictated by the loading method. For example, if the primer is to be the first cartridge loaded into the borehole a priming method should be selected in which the base of the blasting cap is pointing **UPWARDS** toward the main column of explosives. If the primer is to be the last cartridge loaded, a different primer assembly would be called for. Accordingly, a blaster should know how to assemble all four types of primers.

"Side Priming", requires a little more time and effort than other methods, but is strong and very efficient and highly recommended.

1. About one and one-half inches from the top of the cartridge, punch a downward angled hole as shown.....slightly longer than a blasting cap.

2. Insert the cap in this hole so the base of the cap is about in the center of the cartridge and pointing downward. The entire cap should be imbedded in the cartridge.

3. Take a piece of heavy cord about two feet in length. Tie a knot around the fuse about two inches above where it protrudes from the cartridge.....and then take the two loose ends of the string and wind them around both the fuse and the cartridge. Tie firmly and avoid leaving any slack.

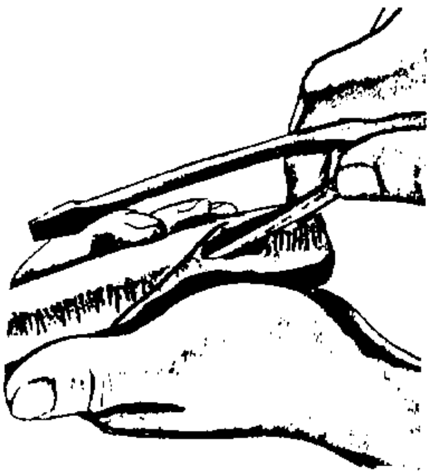

Fig. 12. "Side Priming"

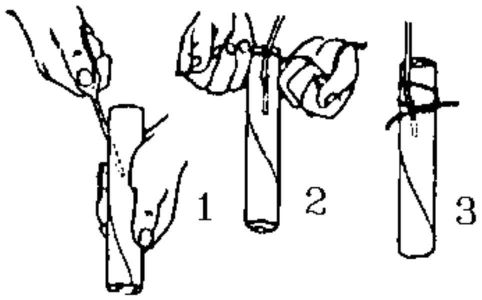

Fig. 13 Side Priming

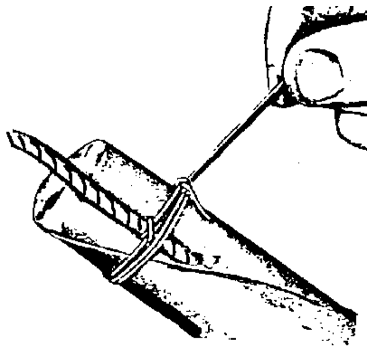

Fig. 14 Side Priming. Finished Cartridge.

Side punching with handle of cutter—crimper.

Fig. 15. Side Priming.

Notes:-

"Top End Priming"

Also known as "Top Center Priming", provides a strong tie and a smaller diameter than side-priming, which may be of concern in some loading situations.

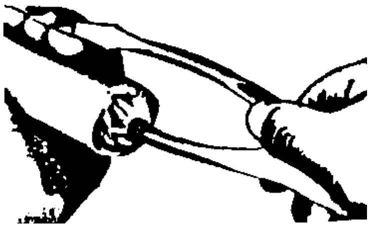

Fig. 16 "Top End Priming".

1. Punch a hole in the center of the top of the cartridge slightly deeper than the length of the cap.

2. Insert the blasting cap and fuse.

3. Firmly tie the fuse to the cartridge. Loop a string around the cartridge several times and then make a knot. Then, bring one loose end up to the fuse and tie it. The fuse should be pulled slightly to one side while being tied.

a] Again, test by pulling on the fuse. The string should take up the strain and the cap should remain in the cartridge.

b] This is probably the easiest loading primer and ideal when working with small or rough drillholes where you have little clearance and wish to protect the fuse from damage.

c] This method is not recommended where the primer is to be the first cartridge loaded into a shot-hole.

d] Top priming is recommended for **"Direct Priming"** that is where the primer cartridge is the last cartridge loaded in the column.

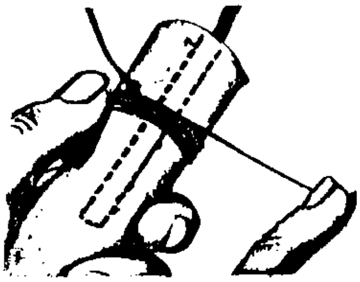

Fig. 17. Top End Priming.

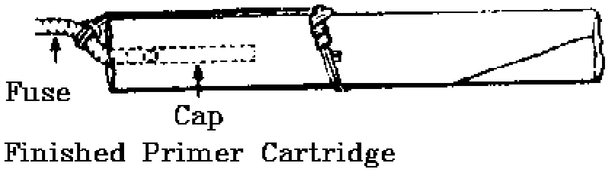

Fig. 18 Finished Primer Cartridge

Fig. 19 Laced Fuse Priming.

"Laced Fuse Priming", is the fastest and easiest method of priming, since no tying is involved. While not as strong as some of the other methods, it is widely used and often adequate.

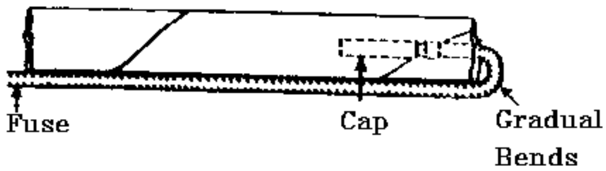

Fig. 21. Bottom Center Priming

Notes:-

In this section, we are dealing primarily with lighting fuse with matches, since this is the method you will probably use most often. However, before discussing the proper techniques of lighting fuse with matches. Let's consider two other methods used.

When a number of fuses must be lighted at the same time, a **"Hot Wire Fuse Lighter"** is often used. This is a stiff wire-covered with a composition which burns slowly with an intensely hot flame. It is much like a fireworks **"Sparkler"**. This lighter is held against the cut end of the fuse, and the intense heat quickly ignites the fuse.

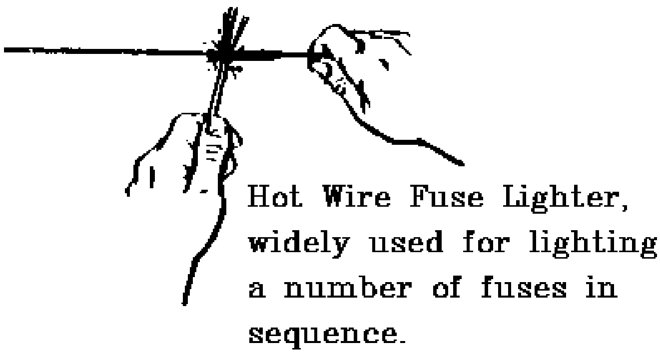

Fig. 22. Hot Wire Fuse Lighter

"Pull Wire Fuse Igniters" are available which slip over the end of the fuse. These light the fuse when the wire is pulled. They contain ignition compounds which are activated by pulling the wire and the fuse is lit with speed and certainty. Such lighters are frequently used commercially and are especially good in wind and rain.

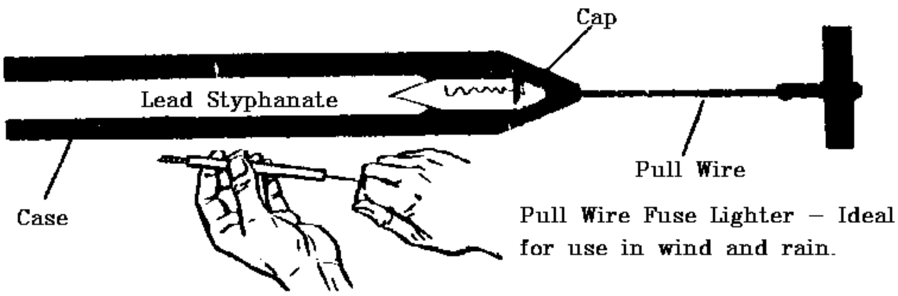

Fig. 23. Pull Wire Igniter.

The only type of matches you should carry when working with explosives are wooden safety matches.....the best are wind-proof wooden matches.....the kind which must be struck on the box before they will ignite. When working with safety fuse you should also carry a clean, sharp knife and cap-crimpers.

The first step is to slit the fuse down the middle for a distance of about one half inch from the end and open this slit carefully so as to expose but not spill the black powder core.

Once the fuse has been split the most common method of lighting is to hold the fuse-end in one hand and place the head of a match downward into the slit and against the powder train. Then, you bring the matchbox up to the match and strike the box against the match. Note that the striking is done with the matchbox.....not with the match.

We prefer a slightly different method of lighting fuse. First, place one match.....head downward.....into the slit in the fuse, with the head in contact with the powder train. Then, we hold another match underneath the first match and light this by striking the matchbox against it. Again, this matchbox is used to do the striking rather than the match. This method provides a more certain concentration of flame at the exact place where it is needed. This method is illustrated below.

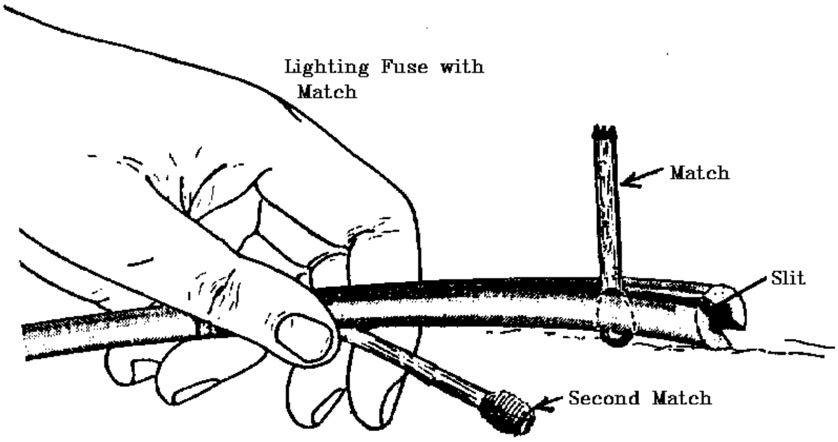

Fig. 24. Lighting Fuse With Matches.

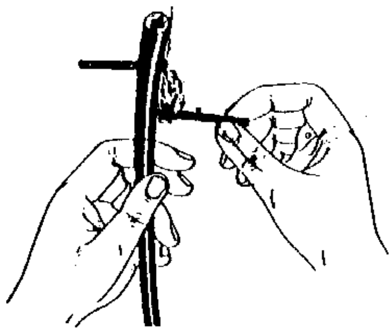

Fig. 25. Lighting Fuse With Match.

Watch for the **"Ignition Spit"** when lighting fuse. When the powder core ignites, a jet of flame shoots out of the end of the fuse which is called the ignition spit. This flame is about one and a half inches long and lasts for about one second.

The **"Ignition Spit", "Signals"** that the fuse has been lit and is burning.

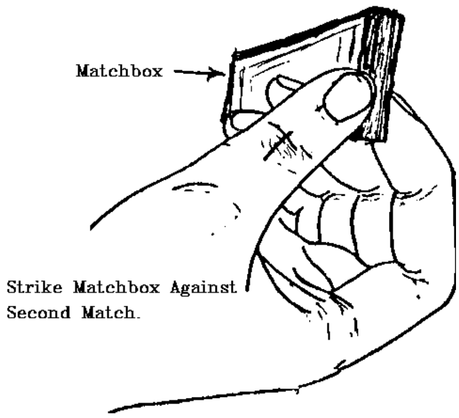

Fig. 26. Lighting Fuse with Matches.

The ignition spit is your best evidence that the fuse has been successfully lighted. You should watch carefully for it. Once this **"Spit"** disappears the fuse will burn internally. It may smoke a little and there may be discoloration of the textile coverings, but the fire will be confined inside the coverings.

It is extremely important from a safety viewpoint to watch carefully for the ignition spit and when you see it assume that the fuse is ignited even if you then fail to see evidence of continued burning. **Men have died because they failed to observe the ignition spit from fuse.**

You should never light fuse with any large flame or burning object such as a glowing coal, blowtorch, flare, etc. These can prevent you from seeing the ignition spit.

In some underground operations the flame from a carbide **"Miners Lamp"** is often used to light fuse. However, under no circumstances should this be done unless there are two or more burning lamps at the scene. There is always the chance that the ignition-spit will blow out the flame in the lamp, leaving the blaster in darkness in the face of an approaching blast!

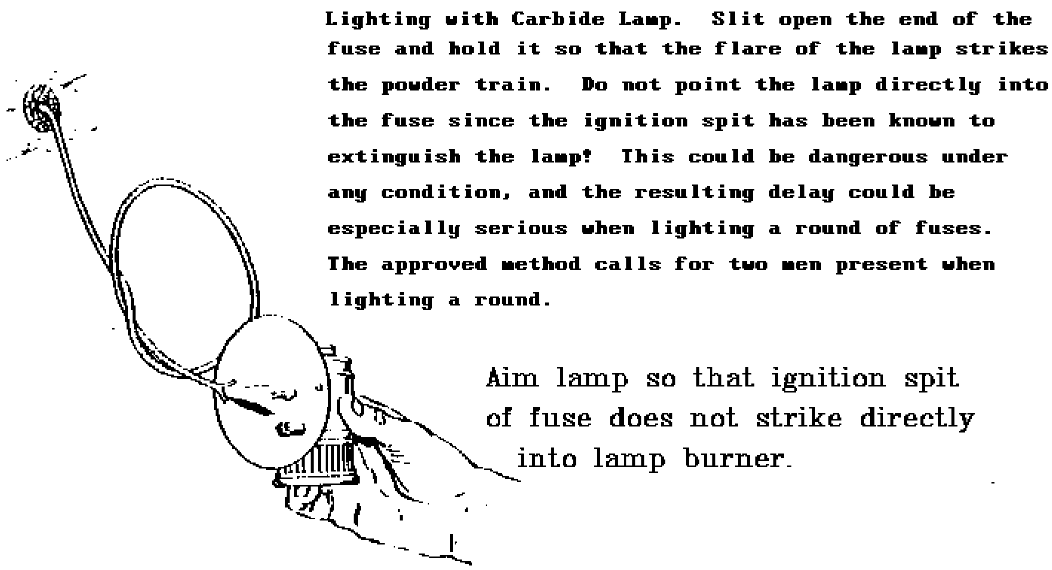

Fig. 27. Lighting Fuse with Miner's Lamp.

After lighting the fuse, Walk, DON'T RUN, to a previously selected place of safety. Watch where you are walking. Pay attention to where you are going, not what is going on back at the blast site!

Obviously, you shouldn't light fuse to initiate a charge until you are sure everyone in the area has been warned and left the site.....or will be leaving with you.....and any explosives and equipment in the area have been removed or protected.

Notes:-

Safety Tips

A list of safety tips applicable to the operations described in this chapter follows and similar safety tips appear throughout this manual.

The reader is urged to learn and follow these safety recommendations to the letter! Safety and skill in the handling and use of explosives cannot be learned by trial and error!

These **"Safety do's and don'ts"** are recommended by the Institute of Makers of Explosives.....People who know what they are talking about.

In some instances our recommendations may conflict with a law, ordinance or regulation in your area. If so, you must comply with your own local laws even if these don't always make good sense.

Chapter II

Safety "Do's and Don'ts"

When Using Explosives

Don't use sparking metal tools to open kegs or wooden cases of explosives. Metallic slitters may be used for opening fiberboard cases, provided that the metallic slitter does not come in contact with the metal fasteners of the case.

Don't smoke or have any matches or any source of fire or flame within 100 feet of an area in which explosives are being handled or used.

Don't place explosives where they may be exposed to flame, excessive heat, sparks or impact.

Do replace or close the cover of explosives cases or packages after using.

Don't carry explosives in the pockets of your clothing or elsewhere on your person.

Don't insert anything but fuse in the open end of a blasting cap.

Don't strike, tamper with, or attempt to remove or investigate the contents of a blasting cap or an electric blasting cap, or try to pull the wires out of an electric cap.

Don't allow children or unauthorized or unnecessary persons to be present where explosives are being handled or used.

Don't use explosives or accessory equipment which is obviously deteriorated or damaged.

Don't attempt to reclaim or to use fuse, blasting caps, electric blasting caps or any explosives that have been water soaked, even if they have dried out. Consult the manufacturer.

When Preparing the Primer

Don't make up primer in a magazine or near excessive quantities of explosives or in excess of immediate needs.

Don't force a blasting cap or an electric blasting cap into dynamite. Insert the cap into a hole made in the dynamite with a suitable punch.

Do make up primers in accordance with proven and established methods. Make sure cap shell is completely encased in the dynamite and so secured that in loading no tension will be placed on the wires of fuse at the point of entry into the cap. When side priming a heavy wall or heavy weight cartridge, wrap adhesive tape around the hole punched in the cartridge so that the cap cannot come out.

When Shooting with Fuse

Do handle fuse carefully to avoid damaging the covering. In cold weather, warm slightly before using to avoid cracking the waterproofing.

Don't use short fuse. Know the burning speed of the fuse and make sure you have time to reach a place of safety after lighting. **Never use less than 6 feet.**

Note Canadian Law States:-

"Do not use less than 6 feet." The shortest safety fuse assembly made/sold in Canada is 6 feet or 2 meters, long. These fuse assemblies are now made up at the manufacturer. Safety fuse and caps are no longer sold separately, in Canada, so that the blaster can make up his own lengths in the field and short-cut the minimum length requirement.

Don't cut fuse until you are ready to insert it into a blasting cap. Cut off an inch or two to insure a dry end. Cut fuse squarely across with a clean sharp blade. Seat the fuse lightly against the cap charge and avoid twisting after it is in place.

Don't crimp blasting caps by any other means other than a cap crimper designed for the purpose. Make certain that the cap is securely crimped to the fuse.

Do light fuse with a fuse lighter designed for the purpose. If a match is used the fuse should be slit at the end and the match head held in the slit against the powder core. Then scratch the match head with an abrasive surface to light the fuse.

Don't light the fuse until sufficient stemming has been placed over the explosive to prevent sparks of flying match heads from coming into contact with the explosive.

Don't hold explosives in the hands when lighting the fuse.

Don't allow any instructions or any set of rules take the place of thoughtful caution and common sense when handling or using explosives.

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Chapter III

Electric Firing

Electric firing systems are used on most large blasting operations, where numerous charges are to be shot at the same time, or in sequence at short intervals, electric firing is considered the most convenient and economical. And, because of the water resistance of the components, electric firing also lends itself to blasting under very wet conditions.

This method offers one convenience and safety feature not found in firing with cap and fuse. That is, that the precise instant of firing, can be controlled. The electric power source is not connected to the blasting circuit until just before the shot is to be fired, and the blaster controls the exact moment of the blast through the operation of the power source.

It may be unnecessary for the farmer, small contractor or other individuals using explosives occasionally for small projects to utilize electric firing. Most small blasting operations can safety and efficiently performed with cap and fuse and detonating cord. However, if you have occasion to work on larger construction projects you will most likely encounter electric firing systems.

Before becoming involved in any but simple electrical firing, you should have a good basic understanding of electricity and circuits. Larger, more complicated blasting circuits should be designed and tested by an Electrician, **Electrical Engineer,** or **Consultant of the Explosives Manufacturer, or Explosives Engineer.**

The latter of **International Society of Explosives Engineers**

29100 Aurora Road

Cleveland, Ohio 44139-1800 USA

Telephone :-[216]-349-4004 Fax:- [216] 349 - 3788

These Professionals are trained through years of experience in All Fields of the Explosives Industry and can be consulted on any aspect of simple to multiple-shot controlled blasting

There are certain added dangers in electric firing, such as the possibility of charges being exploded by stray electrical currents. Special precautions must be observed, which will be discussed later in this chapter.

Notes:-

The Components of an Electric Firing System

1. Electric Power Source:- Which may be a battery; a twist or push-type generator blasting machine, a condenser discharge blasting machine, a portable electric generator, or a AC power line.

2. Wires.

a] Leading Wire:- Sometimes called **"Firing Wire"** or **"Shooting Lines"**, which connects the power source to the blasting circuit. This should This should be a two conductor solid copper wire, well insulated not less than 14 gauge, and at least 250 feet in length for small blasts and much longer for large blasts.

b] Connecting Wire is a smaller, solid copper single conductor insulated wire used to connect individual charges which are too far apart to be connected by simply joining the leg-wires on the caps. This is usually destroyed or damaged by the blast and should not be re-used.

c] Leg Wires:- are short wires attached to and a part of electric blasting caps. They are most often made of copper and plastic covered. When the cap is taken from the carton the leg wires are short-circuited by a **"Shunt"**.....a foiled wrapper which shorts out the bare ends and insulates the wires against contact with electrical currents, thereby reducing the chances of the cap being fired accidentally by stray electricity. The shunt should never be removed until the loading is completed and the cap is to be tested and connected into the blasting circuit.

3. **Electric Blasting Caps** May be either instantaneous firing or delayed firing type.

4. **Primer Cartridge:-** a properly assembled and positioned combination of an electric blasting cap and a high explosive cartridge.

Certain testing equipment is needed. **A Blasting Galvanometer is a must!** Optional testing equipment would include a blasting voltohmeter and a special Rheostat for testing blasting machines. Other necessary equipment includes wire-cutters and pliers, electrician's or plastic tape and a dynamite punch.

Blasting Galvanometers and voltohmeters are especially designed for testing blasting circuits. They contain special limiting resistors, and are powered by special batteries. The use of other galvanometers.....or the use of a standard battery in these instruments.....may result in sufficient currents to accidentally fire the charge while testing the circuit! Accordingly, never try to improvise a circuit tester. Use only those instruments and replacement batteries and parts which have been specifically for testing blasting circuits.

Now, let's look at the **"Instantaneous Electric Blasting Cap",** sometimes referred to as an **"E.B. Cap"** Like the fuse blasting cap it is a thin metal shell containing various sensitive ignition powders and primarily initiating high explosives sealed in a waterproof assembly. Unlike the fuse blasting cap, the electric cap has no open end. It is completely sealed with water-resistant plugs and compounds, with only two insulated **"Leg-Wires"** emerging. Caps are available with leg wires from about four feet to about one hundred feet in length.

Inside the cap, the leg wires are joined by a short piece of a fine resistance wire called a **"Bridge-Wire",** which is imbedded in an ignition mixture. When an ample electric current passes through this bridge-wire it heats it to incandescence. This ignites the ignition mixture and initiates the primer and base charges in the cap.

The electrical blasting cap converts a relatively small amount of electrical energy into a primary-initiating explosion capable of detonating cap-sensitive high explosives with which it is in intimate contact.

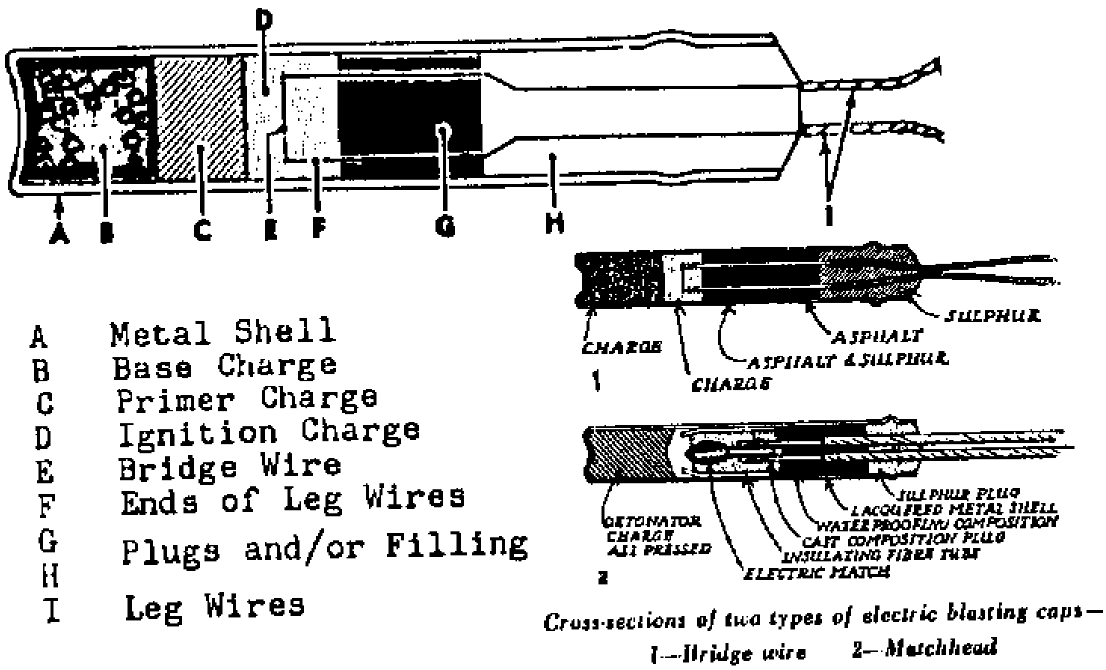


Fig. 28. Electric Blasting Cap.

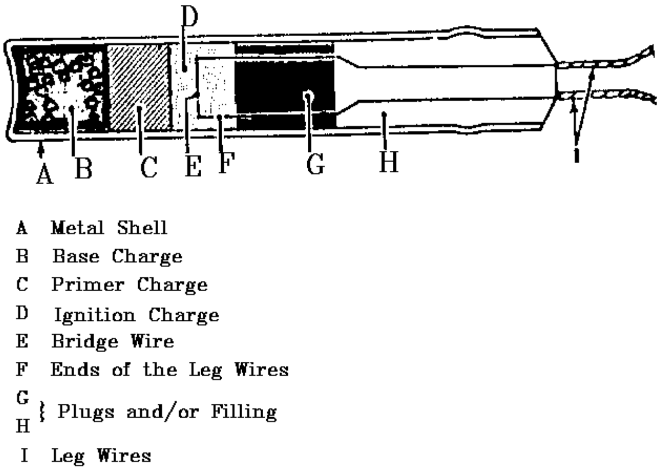


Fig. 28[a]. "Cross-Section of Electric Blasting Cap"

"Delayed-Firing Electric Blasting Caps" are similar to instantaneous caps in construction and action, except that between the ignition charge and the primer charge there is a column of powder called a **"Delayed Charge"** which serves as a time fuse.

Delay E.B. Caps are of two general types.....Millisecond, and long-period delay.....a wire choice of delay intervals are available, running from about 25 milliseconds **[a Millisecond is one-thousandth of a second]** through to about twelve seconds.

Because of the column of delay powder, delay firing caps are usually longer than instantaneous caps. The exact length will vary with the interval and manufacturer. However, delay caps are generally from about one and one-half inches to three inches in length.

It is extremely important that ignition be initiated in all caps in a round before the first cap detonates! To ensure this, use only caps of the same make and type in a round, and provide adequate electrical current! Failure to do so may result in one of more of the charges being exposed before all the caps in the round have reached ignition temperatures, which can result in the first explosions cutting off the wires to uninitiated caps and causing misfires.

The blaster can further reduce the possibility of cap failure by testing each cap with his blasting galvanometer before using it. While caps are manufactured with great care and under strict controls. There may be defects in manufacture or caused by improper handling or storage. Blasting circuits and wire connections must also be tested to reduce the possibility of misfires. The use of the blasting Galvanometer in performing these tests is discussed later in this chapter.

Earlier, we mentioned the sources of electrical power which may be used in electric firing systems. You should understand one important point about electric power requirements in blasting. If the electrical power supplied is inadequate, one or more of the electric caps in a round may not be raised to ignition temperatures before the first cap explodes and cuts the current. This results in dangerous and time-wasting misfires. The electrical energy must be adequate to instantly ignite the ignition mixture in each and every cap before the first cap explodes. Then, when the first cap explodes and cuts off the power it doesn't matter.....because all the other caps are already burning and will detonate in their proper sequence.

If you take a small dry cell battery and hook it directly to the leg wires of a blasting cap having four-foot leg-wires.....the cap would doubtlessly detonate. It doesn't require much electrical energy to initiate a cap under such circumstances. However, when you are working with electric blasting circuits much more energy is required, because you have the problem of **Resistance!**

You have the resistance of double conductor leading wire at least 250 feet in length.....the resistance of all connecting wires.....the resistance created by all the wire connections in the circuit.....and the resistance of each and every blasting cap in the circuit.

So, the problem is not simply to provide the amount of electrical energy needed to fire an electric blasting cap, but rather to provide that amount of energy needed to pass through the entire circuit.....all of which is robbing electrical energy.....and raise the temperature of the bridge wire in each and every cap in the circuit to the ignition point, before the first cap explodes.

Under some circumstances, when other means of firing are unavailable, a small, nearby single charge could be fired by a wet cell battery from a truck or tractor, or by a heavy duty dry cell. However, this should only be attempted as a last resort and when only one cap is involved and the charge is sufficiently small to permit the use of a short leading wire.

The Generator Blasting Machines illustrated below, are commonly used in electrical blasting.

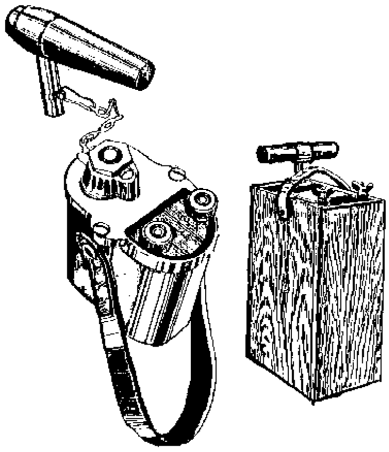


Fig. 29. Generator Type Blasting Machines.

The left illustration shows the hand-held **Twist-Type** generator capable of firing up to ten caps in a simple series circuit. The right is a **Push-Down Type** blasting machine **capable of firing from 50 caps in series to up to 200 caps in parallel series.** These are modified, shunt wound generators which deliver a pulsing direct current at the of the stroke, at which time the current released is close to its peak amperage and voltage.

The firing capacity of these generator type machines is rated by the number of instantaneous E.B. Caps with thirty-foot leg wires they will fire in a straight series circuit.

In order to achieve the full firing capacity of generator type blasting machines, the operator must apply as much power as he can throughout the twist or stroke. The faster the twist or stroke, the more current which is produced. Their design is such that no current flows from the machine until the end of the twist or stroke.

The **Twist-Type Machine** is operated by holding it in the left hand-palm at the bottom of the machine and the strap over the back of the hand......and giving the handle a quick hard twist in a clockwise direction as far as it will turn. Keep the terminals away from your body!

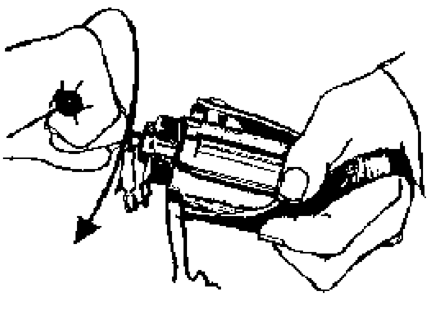


Fig. 30. Holding & Operating a Twist-Type Blasting Machine.

The **Push-Down Type** must be placed on a solid, level ground surface, so the operator is on the opposite side of the machine to the terminals. The rack bar is lifted up as far as it will go, and then driven down as far as possible with a powerful, quick stroke.

To develop full firing capability from a twist-type machine you must try to twist the handle off! With the Push-Down Type, try to knock the bottom out of the machine!

Before using generator machines, it is a good practice to test and loosen them by operating the handle a few times before hooking them up to the firing circuit. This is especially true if the machine has not been used recently or the weather is cold.

A more recently developed type of electric blasting machine is called the **"Condenser Discharge Machine"**. This does not rely upon a hand-operated generator, but rather on dry cell batteries which are used to energize a bank of condensers. Generally, the condensers are charged by pressing a **"Charge"** button or switch and when the machine signals it has been charged.....usually between 5 and 30 seconds later.....the **"Fire"** button is pressed and the shot fired.

Condenser discharge blasting machines are considered the most reliable means of electric firing. They operate efficiently at all temperatures normally encountered. Although the batteries should be kept warm on very cold days. They are available in many models, capable of firing from a few caps to over a thousand caps.

Alternating current [AC] power line installations are used for the electric firing of explosives in some mines, tunnels and other operations where blasting is more or less continuous. These are often high voltage circuits which must be designed by an Electrician, Electrical Engineer, or Explosives Engineer experienced in blasting circuitry. These circuits are beyond the design capability of most blasters...vary greatly.....and will not be discussed further.

Portable power plants are occasionally used for electrical blasting, but are not sufficiently common to warrant further study.

Regardless of what type of electrical source is being utilized in blasting, only one person in a blasting crew should have the authority to hook up the blasting machine to the blasting circuit. He should keep the machine under his control, in a place removed from the leading wires. He should **"Shunt"** or short-circuit the leading wires at the machine end, and remove the blasting machine after shooting. He should not attach the machine to the firing circuit until just before a shot is to be fired, and only after he/she is sure the blast site has been vacated.....that all personnel and equipment have been removed. He/She will then attach the machine to the leading wire ends. When he/she gives or hears the signal for firing he/she will then activate the firing mechanism by inserting the handle.....lifting up the handle.....or pushing the **"Charge"** button. He/she will not fire, however, until he/she is sure in his/her own mind that everything is in order. After firing, he/she will disconnect the machine.....remove it to a place of safe-keeping away from the leading wires.....and short circuit the leading wires at the blasting machine end.

<u>NOTES:-</u>

Making Primer Cartridges for Electric Firing

In a previous chapter you learned the general guidelines for making primer cartridges. These also apply to primers made for electric firing.

Many of the principles and techniques described in material dealing with making primer cartridges for fuse firing also apply to making electric primers and will not be repeated.

The primer cartridge for electric firing must be assembled in such a manner that the cap is unlikely to be pulled from the cartridge during loading and is positioned in the cartridge in a manner which will protect it from abrasion and ensure efficient detonation of the primer cartridge and the main explosive charge. Primer cartridges for electric firing are almost invariably **"End-Primed".**

The most common method of making a primer is to punch a deep hole in the center of one end of the cartridge, then merely insert the cap and make a half-hitch with the leg wires around the center of the cartridge, as illustrated in the next diagram on the left. The assembly is made stronger if it is tied with a **"Girth Hitch".....**or two half-hitches.....as shown in the next diagram on the right.

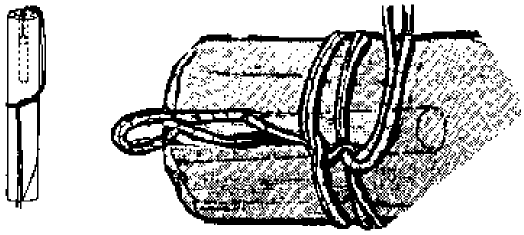


Fig. 31. Girth-Hitch.

Another method of making primers for electric firing is illustrated on the left. In this method a hole is punched for the cap in one end of the cartridge and another hole is punched horizontally through the cartridge.

A loop is formed in the leg wires, which is passed through this horizontal hole. It is opened up on the other side, brought down and looped over the bottom of the cartridge and pulled taut.

In the third method approved for priming small diameter cartridges, one hole is punched horizontally through the cartridge slightly below the center.....and another in the far end of the cartridge for the cap.

The cap is pushed through the horizontal hole.....then into the hole in the top of the cartridge.....and the wires pulled taut.

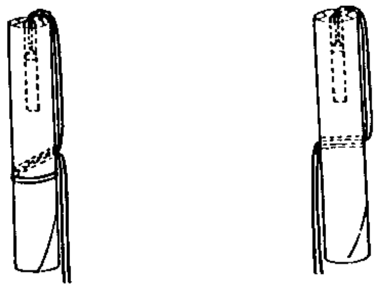


Fig. 32. Lacing E.B. Cap-Wires.

Fig. 33. Lacing E.B. Cap-Wires.

NOTES:-

Electric Blasting Circuits

There are three types of circuits commonly used in electric blasting. They are Series, Parallel and parallel series circuits. We show each of these types of circuits below.

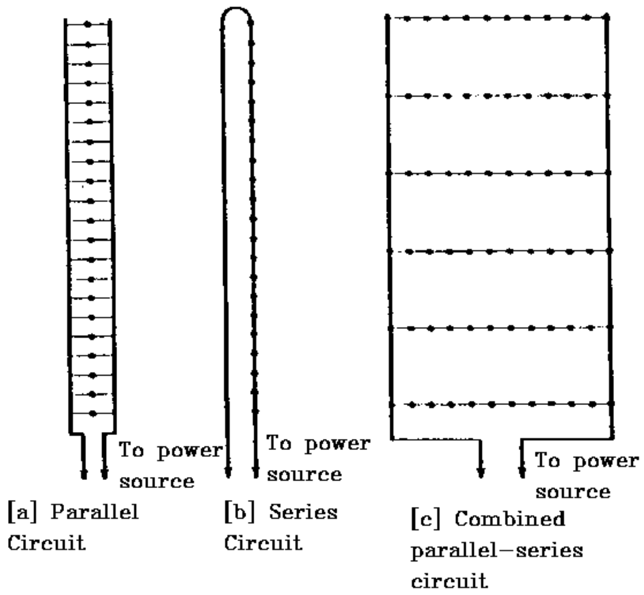


Fig. 34. Electric Blasting Circuits.

Series circuits provide a single path for the current through each blasting cap in the circuit. Charges are most commonly connected in series by merely connecting a leg-wire of the cap in the first charge with one leg-wire of the cap in the second charge.....the other wire from the second cap to the leg-wire on the third cap.....and so on. After all these connections are made only two unconnected leg-wires remain.....one from each of the first and last charges. These are then connected to the leading wires or firing lines, which are in turn connected to the power source.

In cases where the distance between the caps is greater than can be spanned by the leg-wires, connecting wire must be used to join the caps. However, electric blasting caps may be purchased with long leg-wires and it is much better to use caps with longer leg-wires than to use connecting wire.

The use of connecting wire increases the number of wire connections or splices, the total resistance of the circuit, and the chances of error. Also, connecting wire is an added expense in terms of both time and material. It should never be re-used, even if it appears to be still intact and in good condition.

Series circuits will be adequate for the needs of the vast majority of readers.

Here is an illustration of a Simple Series Blasting Circuit.

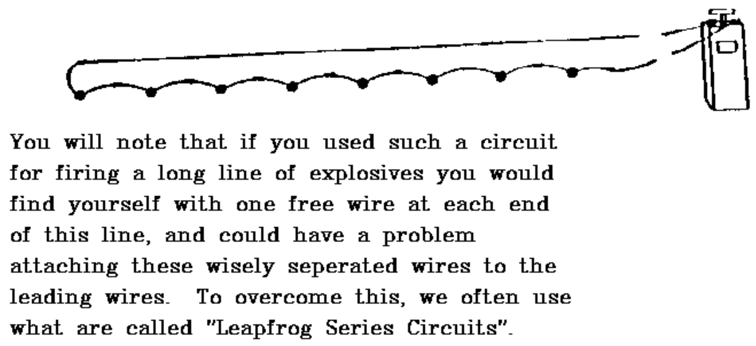


Fig. 35. Simple Series Blasting Circuit.

You will note that if you used such a circuit for firing a long line of explosives you would find yourself with one free wire at each end of this line, and could have a problem attaching these widely separated wires to the leading wires. To overcome this, we often use what are called **"Leapfrog Series Circuits"**.

Fig. 36. Leapfrog Series Circuits

From the above illustration of a **"Leapfrog Series Circuit"** you will see that what we have done is merely omit the alternative charges on the way out from the first charge and pick these up on the way back, thereby providing a return path for the current. This brings both wires out at the same end of the line of charges and eliminates the need of running an extra wire from the far end of the line.

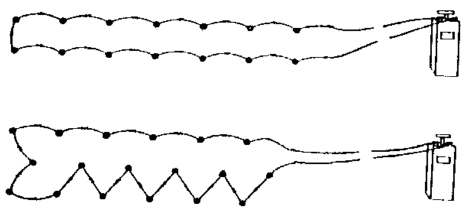


Fig. 37. Simple methods of connecting two and three lines of charges in series.

Note in both of these illustrations how the wire-ends which will be attached to the firing lines and the blasting machine have been brought to the same end of the lines of charges.

Next we have the **"Parallel Circuit"**, in which one leg-wire from each blasting cap is connected to a wire running down one side of the blasting circuit, and the other leg-wire from each cap is connected to a wire which runs down the other side of the circuit.

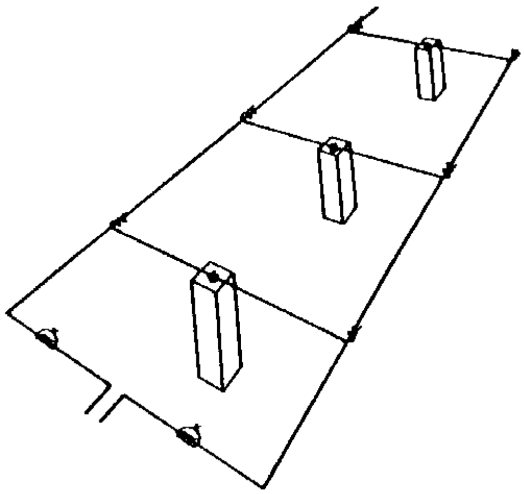


Fig. 38. Parallel Circuit.

Parallel Blasting Circuits usually require power greater than that provided by generator-type blasting machines. They are most commonly used where there are high voltage power lines **[AC]** as the power source.

Finally, we have **"Parallel Series Circuits",** sometimes referred to as **"Series-In-Parallel" or "Series-Parallel"** circuits. These are really just a combination of two or more series circuits joined to make a closed loop circuit. Then, one leading wire is connected into the loop, and the other leading wire is connected into the loop and the other leading wire is connected at a point halfway around the loop.

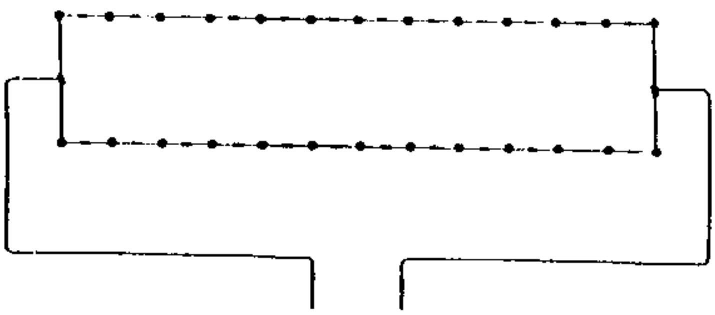


Fig. 39. Parallel Series Circuit.

The advantage of the parallel series circuit is that a larger number of caps can be fired by a given power source than could be fired if the caps were placed in a straight series circuit. The so-called **"50-Cap Blasting Machine",** which is capable of firing up to 50 caps in series **will actually fire up to 200 caps under favorable conditions in Parallel-Series!**

It is felt that the series circuits illustrated in this manual will be adequate for the needs of most readers under most circumstances. However, for those who must work with parallel and parallel-series blasting circuits, keep the following in mind:

1. **Use only one type or make of blasting cap in a circuit. The electrical characteristics of different caps of different makes are dissimilar.**

2. **When two or more series are connected in parallel, place the same number of caps in each branch;**

3. **In parallel-series circuits use identical leading wires of the same lengths; and**

4. **Pay particular care to insure that all connections are tight, because loose connections can cause "Unbalanced Circuits" through increasing resistance.**

NOTES:-

Splicing and Connecting Wires in Electrical Blasting Circuits

It is extremely important that all splices and electric connections be made carefully for a number of reasons. A faulty connection may interrupt the circuit and cause failure to fire.

Poorly made connections add greatly to the total resistance of the circuit and may raise the resistance above the capability of the power source. Poor connections and splices may raise the tensile strength of the wires, permitting them to pull apart under the strains you must expect during loading and other field operations, and connections and splices can provide a means of stray unwanted electrical currents entering the blasting circuit and causing unwanted detonation.

It is dangerous and time-consuming practice to fail to take ample time and care in making electrical connections and splices.

Before connecting any two wires, the insulation, if any, must be completely removed from the area in a manner which will not cut or nick the wire.....an enamel or coating on the wire must be removed.....and any dirt or corrosion cleaned off.....so that bare wire is exposed. Careful scraping with a knife blade will usually do the job. If stranded wires are involved, they should be twisted tightly after scraping.

Protect all bare wire splices and connections in blasting circuits to prevent their short-circuiting to the ground or each other. Insulate bare wires from the ground or other conductors by wrapping with tape, and/or support them on blocks of wood or other non-conductive material.

No un-insulated wire should ever touch the ground!

The most frequent wire connection in blasting is joining the leg-wires of two blasting caps. The recommended method of doing this is:-

1. **Hold the two bared leg-wires together.....side by side with both ends pointing in the same direction:**
2. **Bend both together at a point about the middle of the bared portion, folding over to form a loop; and**
3. **Twisting this loop several times.**

This forms a strong and low resistance connection, as shown below. With a little practice you should able to make it in three or four seconds. One advantage of this connection is that it tends to become tighter if pulled.

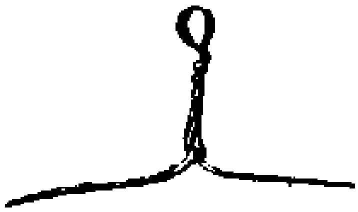


Fig. 40. Pig-Tail Splice.

Notes:-

The **"Western Union Splice"** is widely used and highly recommended for making other wire connections. The method of tying is strong, low resistance splice is shown below.

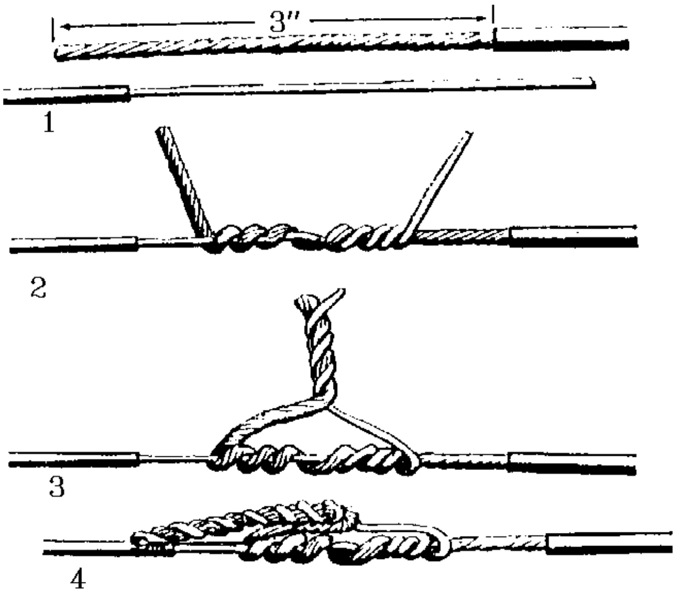


Fig. 41. Western Union Splice.

In attaching leg or connecting wires to heavy wires such as bus wires.....where the smaller wire will connect at an angle of about ninety degrees.....wrap the smaller wire around a few tight turns, leaving about one inch of free wire. Then, bend this free end sharply to parallel the larger wire and cross to the other side of the light wire and make another couple of tight turns around the larger wire.

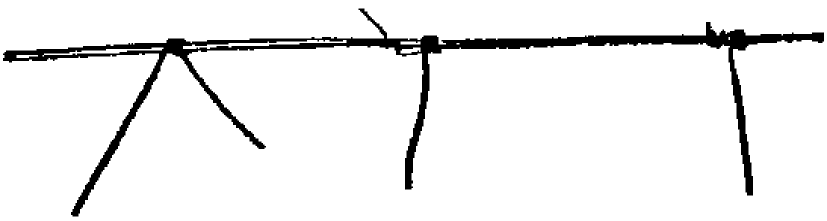


Fig. 42. Attaching Leg-wires to Heavy Connecting Wires.

In making wire connections and splices, keep in mind the two important requirements.....strength.....and intimate contact to provide low resistance.

Whenever possible, one person should be responsible for all wiring in a blasting circuit, and make all the connections in order to prevent misfires he/she should be sure that all blasting caps are included in the firing circuit.....all wire connections are properly made so as to provide high strength and low resistance.....short circuits and grounds are avoided.....and the number of caps in any circuit and/or the total resistance of the circuit does not exceed the rated capacity of the power source.

Wiring like all other steps in handling explosives and preparing a shot, requires care and attention to detail. **Sloppiness will result in misfires.....which are both costly and dangerous.....or accidental detonation.**

Notes:-

Calculating Resistance and Power Requirements

In smaller blasts fired electrically, charges are usually connected in a series and fired by a blasting machine. The rated capacity of the machine is not exceeded. Components and circuits are tested to insure that there are no shorts or breaks in the circuit, and there are no defective components, poor connections or other sources of high resistance.

It is a good practice to calculate the approximate resistance of the circuit beforehand. In this manner, you will recognize a reading which is too high.....and suggests you have a short circuit.....or too low.....and suggests you have poor connections.

Each blasting circuit is composed of electric blasting caps and various lengths of various gauges of wire.

Each of these components have resistance which must be calculated and added together to give us the total resistance of the circuit. It is this total resistance which we must consider when laying out a blasting circuit to be fired by a given power source, or when calculating the power requirements for a given blasting circuit.

In smaller series blasting circuits likely to be used by the reader, the blasting caps constitute by far the greatest resistance. **The resistance of heavy leading wire.....which must be at least 14 gauge, and heavier for longer shots.....is extremely low.** Consequently, when working with smaller circuits in the field we generally ignore the resistance of the leading wires and calculate the approximate resistance of the circuit by considering the blasting caps alone.

Notes:-

The table which follows shows the resistance of DuPont instantaneous firing electric blasting caps with copper leg-wires. The length of the leg-wires is in feet, the resistance in ohms.

Length of Leg-wires	Resistance per cap	Length of leg-wires	Resistance per cap
4 feet	1.26 Ohms	24 feet	2.07 Ohms
6	1.34	30	1.71*
8	1.42	40	1.91
10	1.50	50	2.12
12	1.58	60	2.32
14	1.67	80	2.72
16	1.75	100	3.13
20	1.91		

Note, that heavier leg-wires are used on caps with 30' and longer wires.

Delay-firing caps have **0.10 Ohms LESS RESISTANCE** than instantaneous caps with the same length of leg-wires.

Working with this table, you will see that if you had a blasting circuit which contained 10 instantaneous DuPont caps with 16-foot leg-wires, the total resistance of the caps in the circuit would be **17.5 Ohms.**

Number of caps, 10.....times resistance of each cap.....from the table, 1.75 Ohms.....gives 17.5 Ohms.

Or taking another case where you have 25 caps each with 20-foot DuPont copper leg-wires, the resistance of the caps in the circuit would be **47.75 Ohms.**

Number of caps, 25.....times the resistance of each, from table, 1.91 Ohms.....gives 47.75 Ohms.

If preliminary testing showed a resistance much higher than you calculated, you would check for one or more poor connections. If it showed much less than you had calculated, you would be highly suspicious of a short circuit.

The tables which follow are provided for the reader, who may wish to make more advanced calculations. Such calculations are seldom required of blasters in the field.

Calculations for a Series Circuit

Current Requirements:- 1.5 amperes, regardless of the number of caps in the circuit. Resistance has been previously discussed.

Voltage Requirements:- $E = IR$, or, multiply the required current of 1.5 amps by the resistance.

Power Requirements:- $W = I^2R$, or, multiply the square of the current required by the resistance.

Calculations for a Parallel Circuit

Current Requirements:- 0.6 amperes per cap.

Voltage Requirements:- $E = IR$

Power Requirements:- $W = I^2R$

The resistance of a balanced parallel circuit is less than that of a series circuit comprised of the same components, because the electricity has more paths through which to flow, and the same voltage will push more amperes of current through the parallel system. The total resistance of a balanced parallel system is equal to the resistance of one branch.....or one cap.....divided by the number of branches. To this must be added the resistance of the wires. It is customary to include the resistance of the leading wires, but only one-half of the resistance of the bus wires.

Notes:-

Calculations for a Parallel Series Circuit

Current Requirements:- 1.5 times the number of series connected branches that are parallel.

Voltage Requirements:- E = IR, or multiply the required current by the resistance.

Power Requirements:-

$W = I^2R$, or multiply the square of the required current by the resistance.

The following table shows the resistance.....ohms per thousand feet.....of various AWG gauges of copper wire.

Gauge	Resistance	Gauge	Resistance
4	0.3 Ohms	14	2.5 Ohms
6	0.4	16	4.0
8	0.6	18	6.4
10	1.0	20	10.2
12	1.6	22	16.1

Testing Electric Blasting Circuits

Causes of misfires in electric blasting circuits include:

Power Sources.....An inoperative or weak blasting machine.....incorrectly operating the machine.....or trying to fire more caps than the machine is rated to fire.

Blasting Caps.....Caps which are defective or have been damaged during storage, handling or loading.....or using different makes or types of electric blasting caps in the same circuit.

Wiring..... Poor electrical connections which cause a short circuit, a break in the circuit, or high resistance.....circuits which are damaged during loading or other activities at the site.....or failing to hook up one or more charges in a round into the blasting circuit.

These deficiencies can usually be all but eliminated by carefully following recommended procedures and testing all blasting circuits and components before attempting to fire a shot.

The basic instrument for testing is known as the **"Blasting Galvanometer"**. With this, we check the functioning of the various parts of the firing system such as the caps, wires, connections and splices and complete circuits.

The blasting galvanometer has a dial with an indicator needle. When the two external terminals of the galvanometer are connected to a closed circuit, the flow of current from a dry-cell battery causes this needle to move across the scale. The degree of deflection.....or the reading.....will vary with the resistance. The greater the resistance, the less the needle will deflect.

If you have previously estimated the approximate resistance of the circuit in the manner described, you know approximately what reading to expect on the galvanometer. Too high a reading would indicate a short. Too low a reading could indicate poor connections.

No reading could indicate a break in the circuit.

The galvanometer should be tested before being taken into the field, by holding a piece of bare wire across the two terminals. This should cause maximum deflection of the needle. If it doesn't, then the battery probably needs to be replaced or perhaps the instrument has been damaged.

Keep in mind that a dry-cell loses much of its energy in cold temperatures and this will cause inaccurate readings. So, protect the galvanometer during very cold weather by carrying it under your clothing next to your body. Protect it from moisture and handle it carefully.

The blasting galvanometer contains a special battery and special limiting resistors to insure that the maximum current at the terminals is less than one-tenth of the current needed to fire an electric blasting cap. **Other galvanometers, or blasting galvanometers in which regular batteries have been substituted, are likely to fire the circuit during testing!**

Accordingly, never test a blasting circuit or component with any instrument which has not been designed specifically for blasting, and use only proper replacement batteries in such instruments!

Before assembling a primer cartridge test the electric blasting caps to be used. It only takes a moment and is good insurance. Unwind the foil or shunt from the leg-wires and touch one leg-wire to each terminal of the galvanometer. There should be maximum deflection of the needle as illustrated below.

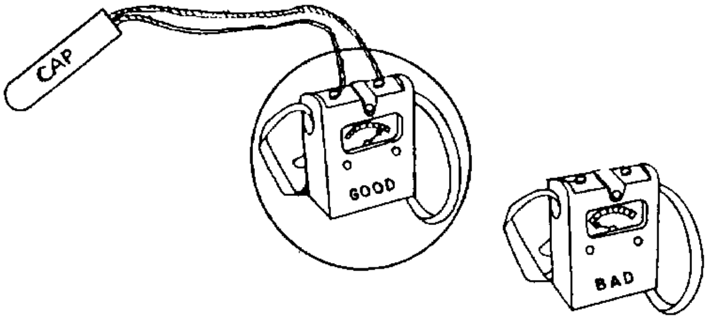


Fig. 43. Testing an E.B. Cap With The Blasting Galvanometer.

If there is little or no deflection of the needle.....and you have previously tested the galvanometer and know it is working properly.....then the blasting cap is electrically defective and should be destroyed.

Caps may be tested again if we find a short or high resistance when we are testing the entire circuit, on the chance that they were damaged during loading. But, it is a good practice to test caps before making up primers, and know that you are at least starting out with good caps.

It should be noted that this testing only identifies caps which are electrically defective. It will not identify a cap which is defective because of an obstruction or some damage or deterioration of the explosive mixture.   **And keep in mind that a cap which proves defective in this test is still a sensitive high explosive and source of danger!**

Loading wires should be tested, **AFTER**, they are uncoiled and laid into position but are still un-attached to either the power source or the blasting circuit. While some persons test their firing wires while they are still coiled on the reel. This is not recommended because often a break in the wire may not become evident until the wire has been stretched out.

The procedure for testing leading wires is as follows. First, separate the bared ends of the wires at both ends. Then, attach the galvanometer to one end. There should be **NO** deflection of the needle. A deflection would show a short circuit.

Then join the bared wires at one end and touch the wires at the other end to the terminals of the galvanometer. There should be considerable deflection. If there isn't, this could indicate a break in the wire.

Notes:-

After testing the blasting caps and the leading wires and being assured that these are O.K., we then test the entire circuit. The wire-ends of the circuit to which we will attach the blasting machine should deflect considerably, indicating the approximate resistance you have calculated. Again, if the needle moves too far, you probably have a short. If it doesn't move at all there is a break in the circuit. Refer to the drawing below.

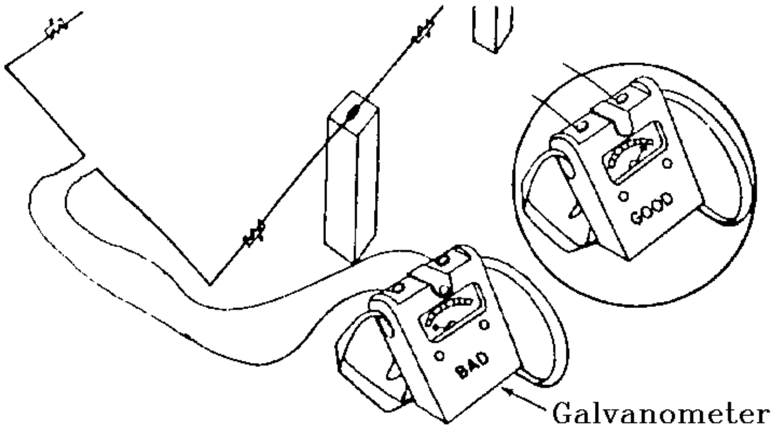


Fig. 44. Testing A Blasting Circuit With The Blasting Galvanometer.

If the galvanometer indicated an incomplete circuit, then you would check each **HALF** of the circuit to find out which half contained the break, as shown below.

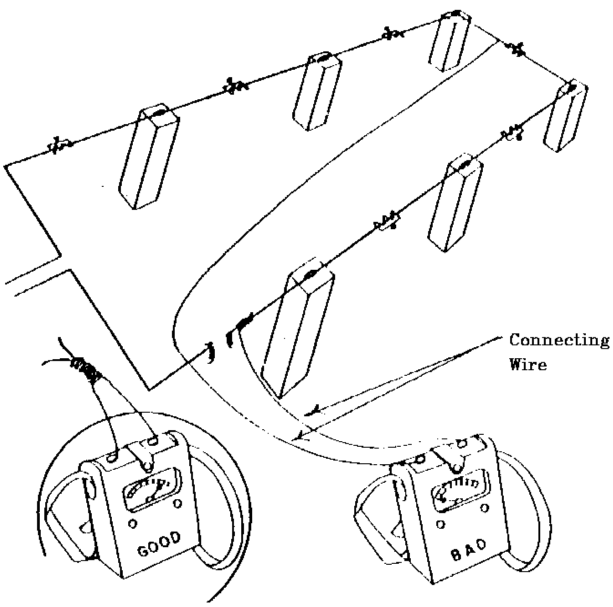


Fig. 45. Testing A Blasting Circuit With The Blasting Galvanometer.

In this case the break would appear to be on the right side of the circuit. If this were a small circuit we would then test each connection and primer on that side as shown below. If it were a large circuit we would first try to narrow down the problem by finding out which quarter or which eighth of the circuit contained the break. Most breaks in blasting circuits occur at wire splices. Test each splice in the defective portion of the circuit, as follows.

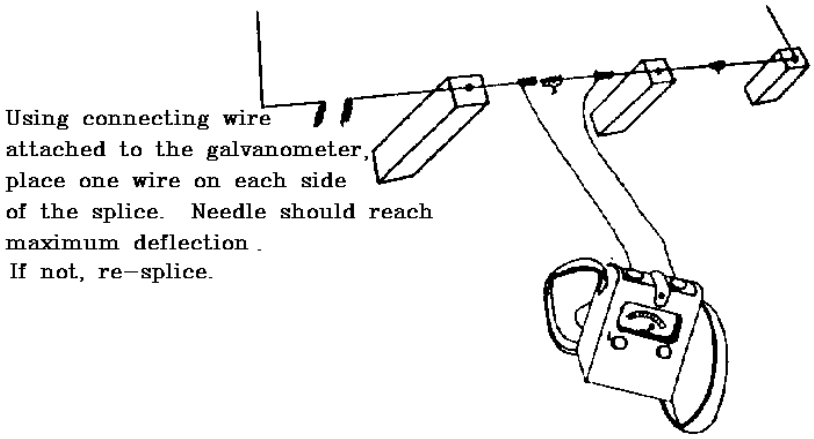


Fig. 46. Testing Connecting Wire Attached to Galvanometer.

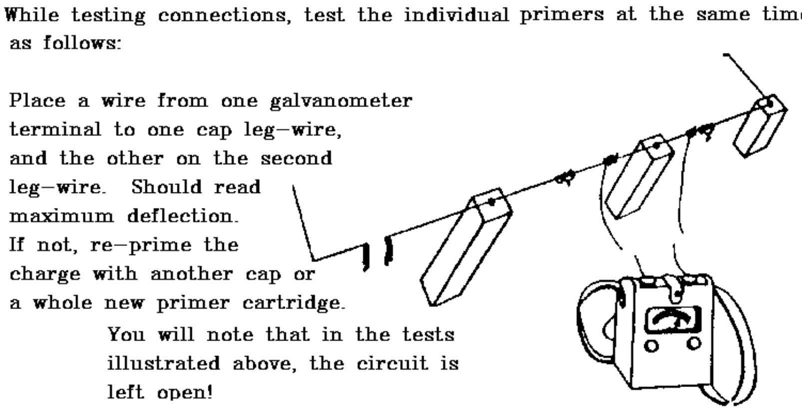


Fig. 47. Testing Electric Blasting Circuit with a Galvanometer.

The readers may question the value of such extensive testing. However, it should become increasingly evident to him as he proceeds through this manual, **THAT MISFIRES ARE EXTREMELY DANGEROUS AND COSTLY**. **THIS WILL BE BROUGHT HOME THE FIRST TIME HE/SHE HAS THE DANGEROUS JOB OF WORKING AROUND A MISFIRED CHARGE !** He/She will then likely join the ranks of the other intelligent blasters who do everything in their power to illiminate misfires.

NOTES:-

The Danger of Extraneous Electricity

If an electric blasting cap will detonate when we intentionally pass a current of less than an ampere through it. It will detonate when such a current passes through it whether this is intentionally or unintentionally!

"Extraneous Electricity" refers to any unwanted electricity which could enter a blasting circuit, and cause an unintended detonation.

While a current of 1.5 amperes is needed to efficiently initiate a blasting cap in series.....and 0.6 amps in an efficient parallel circuit.....as little as 0.25 amperes will fire a cap. Although not with the speed and certainty we must have in blasting! We consider any unwanted electrical current in a blasting circuit in excess of 0.05 amperes as hazardous!

If lightning strikes at or near a blasting circuit. The charge is almost certain to detonate. Accidental detonation has occurred in instances where lightning has struck several miles away! The danger is increased if there are power lines, fences, streams, rails or pipes and other conductors between the strike and the blasting site. **Lightning probably represents the single greatest danger in Electric Blasting.** The only defense is to remain alert to weather conditions and approaching electrical storms.

Operations should be suspended immediately a storm is expected within the area.....or at least by the time it gets within the area.....or at least by the time it gets within eight miles.....and all persons should be removed from the area until the threat has passed.

While lightning is a greater threat when electrical methods of firing are used. It also poses some threat when cap and fuse or detonating cord systems are involved. A direct lightning hit will most likely detonate any un-primed high explosive, even if it is still in its container.....in a truck, in storage, etc.

Static electricity is another source of dangerous electrical current. Very low humidity coupled with dust or snow storms can cause static electricity capable of detonating electrical blasting caps. **So can Static Electricity produced by moving belts, machinery, and other moving equipment and friction-causing activity.**

High potentials of static electricity can be stored on any conductive body insulated from ground, including your own body! If such blasting cap leg-wires touch such a charged body the static electricity may find a path to ground through these wires.....even if they are shunted and insulated.....and detonation may result!

Blasters should avoid certain items of clothing which will expose them to static charges The best work clothing is leather or plain cotton washed only in clean hot water, without using detergents. Nylon, combinations of synthetic fibers, plastics, some resins used in wash-and-wear clothing and even dirt in otherwise safe clothing, can present severe static hazards. The danger is much increased under extremely dry conditions such as found in deserts, extreme cold, high altitudes, etc.

Ideally, no static producing equipment such as moving belts should be permitted at sites of electric blasting. If such machinery must be tolerated, then it should be joined electrically to a good common ground rod.....Well insulated from any pipes or wires. And, all nearby moving machinery and equipment should completely shut down while blasting circuits are being connected and until the blast has been fired!

Batteries, transformers, generators, power lines and other electrical equipment and conductors can, under certain circumstances, cause ground electrical currents. Electric blasting should not be attempted near such equipment or near conductors such as rails and pipes. If blasting must be performed in such an area, then by no means should electrical firing systems be considered until an expert.....**Explosives Engineer/Electrical Engineer**.....has measured for stray ground currents. Preferably, an alternative method of firing should be selected.

A method of testing to determine the presence of extraneous electrical ground currents is to lay out a dummy blasting circuit, substituting a **No. 47 Radio Pilot Lamp** in place of the cap. If any glow is observed in this bulb when viewed in darkness, dangerous ground currents are present and electrical firing methods must not be used.

"Radio Frequency Energy" is another source of potentially dangerous unwanted current, and the site should be surveyed beforehand to locate and identify any nearby radio transmitters. Under certain circumstances, electric blasting cap leg-wires may pick up enough electrical energy from such sources to fire the cap, shunted or not. So, you must be alert to mobile radio transmitters in vehicles. Signs should warn mobile transmitter operators to shut off their transmitters when approaching the area. Fortunately, there appears to be no danger from R.F. energy when caps remain coiled and packed in their original containers, and the dangers from radio frequency energy are probably not as great as one might suspect from the precautions which are taken.

Dangers from R.F. energy and some other stray currents may be reduced by laying blasting caps on the ground so the leg-wires are stretched out flat on the ground. This is a good practice when making up primer cartridges.

NOTES:-

Chapter III

"Safety Do's & Don'ts"

When Shooting Electrically. . .

Don't uncoil the wires or use electric blasting caps during dust storms or near any other source of large charges of static electricity.

Don't uncoil the wires or use electric blasting caps in the vicinity of radio-frequency transmitters, except at safe distances.....Consult the manufacturers or the institute of makers of explosives pamphlet on **"Radio Frequency Hazards".**

Do keep the firing circuit completely insulated from the ground or other conductors such as bare wires, rails, pipes or other paths of stray currents.

Don't have electrical wires or cables of any kind near electric blasting caps or other explosives except at the time and for the purpose of firing the blast.

Do test all electric blasting caps, either singly or when connected in a series circuit, using only a blasting galvanometer specifically designed for the purpose.

Don't use in the same circuit either electric blasting caps made by more than one manufacturer or electric blasting caps of different style or function even if made by the same manufacturer, unless such use is approved by the manufacturer.

Don't attempt to fire a single electric blasting cap on a circuit of electric blasting caps with less than the minimum current specified by the manufacturer.

Do be sure that all wire ends to be connected are bright and clean.

Do keep the electric cap wires or leading wires disconnected from the power source and short circuited until ready to fire.

If you suspect there may be extraneous electrical currents from any source at a proposed blasting site, contact a representative of the manufacturer of your explosives before proceeding further. Explosives manufacturers offer excellent advice and guidance and should be contacted on any technical matter.

"When in doubt about a task, why should you be scared to ask?"

Chapter IV

Detonating Cord

Detonating cord, often called by its trade name, **"Primacord"** and sometimes called simply **"Det Cord",** is an exploding fuse.

Safety fuse contains a core of black powder and burns at a rate of 90 or 120 seconds per yard. Detonating cord contains a core of very high velocity high explosive, and detonates **at a speed of about four miles per second or 27,000 feet per second!**

One of the advantages electrical firing has over firing with safety fuse is that because of the speed of an electrical current that method is more adaptable to firing a number of charges simultaneously. However, with the introduction of detonating cord in 1937, it became possible to explode multiple charges simultaneously with cap and fuse methods and equipment.

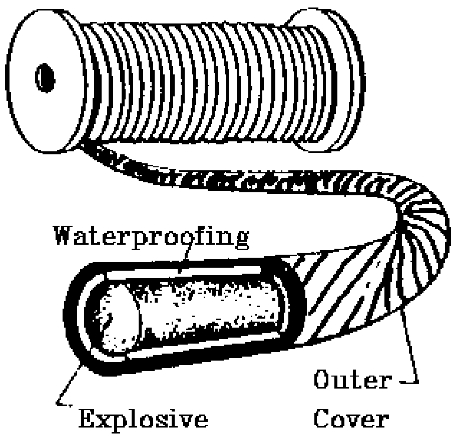


Fig. 48. Detonating Cord.

The explosive core in det cord is usually **PETN** a very **"Brisant"** high explosive which detonates at up to 27,000 per second.

When detonating cord explodes, it sends a shock wave along its entire length which is capable of detonating any cap sensitive high explosive with which it is in close contact. In other words.....detonating cord has the energy of a blasting cap at all points along its length and will detonate other explosives without the need of a blasting cap. In this respect, detonating cord serves as both a high speed fuse and blasting caps.

Imagine a string of numerous explosive charges spread over a distance of a quarter mile. Using detonating cord, the total time which would lapse between the explosion of the first charge and the firing of the last charge located one-quarter of a mile away, would be only one-sixteenth of a second!

Another advantage of **"Primacord"**.....**[a Registered Trademark of the Ensign-Bickford Company]**.....is that it replaces many blasting caps, which are far more dangerous to handle and use than detonating cord. There is a higher degree of safety in handling and loading when using detonating cord than there is when using conventional cap-firing methods. AS far as can be determined, there has never been an accidental explosion of detonating cord caused by shock or impact. **This is one reason why, it has been used so extensively in military operations.**

Detonating cord firing systems are often substituted for electrical methods of firing under conditions when stray electrical currents or radio frequency energy make electrical blasting hazardous.

Standard "Primacord" detonates at speeds of about 21,000 feet per second. Some special cords have a core of R.D.X., and detonate at speeds in excess of 27,000 feet per second. It is classified according to the number of grains of explosives it contains per linear foot. **Cords with core-loads of as low as 18 and as high as 400 grains per foot are available**, but those most commonly used are from 25 to 60 grains per foot. Any of these strengths are capable of initiating any cap-sensitive explosive along their length.

In appearance, detonating cord closely resembles safety fuse. It is covered by similar combinations of textiles and waterproofing compounds to provide strength and flexibility and resistance to abrasion and water. The core is a white crystalline solid and different colored outer coverings are used for identification.

You can't light detonating cord with a match! It functions by exploding.....Not Burning.....and like most other high explosives it requires a primary-initiating explosion provided by a blasting cap to cause it to detonate. The usual method of initiating detonating cord with safety fuse is to securely tape a fused blasting cap to the side of the detonating cord, using plastic or electrician's tape, and detonate the cap. A similar procedure is followed in initiating detonating cord with an electric cap.

It is very important that the base of the blasting cap be pointed in the direction you want the explosion to travel down the detonating cord! It is also important to avoid having any tape or other material between the cap and the detonating cord.....they must be in direct contact. And, the cap should be taped to the detonating cord at least six inches from the cut end of the cord!

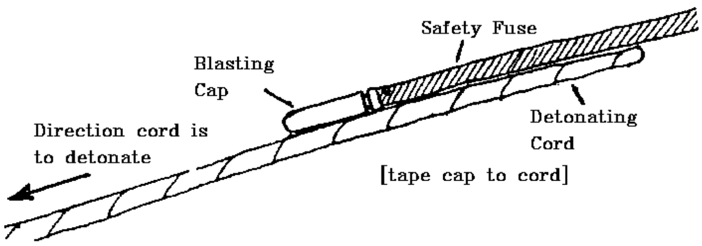


Fig. 49. Detonating Cord Primer.

When working with detonating cord, it's a good idea to always carry plenty of plastic tape, not only for attaching blasting caps, but also for holding the cord to explosive cartridges when priming.

Another good practice is to tape your safety fuse primer to a short length of detonating cord.....eighteen to twenty-four inches long. This is called a **"Pigtail".** Immediately before blasting you tie this pigtail to the end of the main line or trunkline of detonating cord. This keeps the sensitive blasting cap out of the picture until the last possible moment.

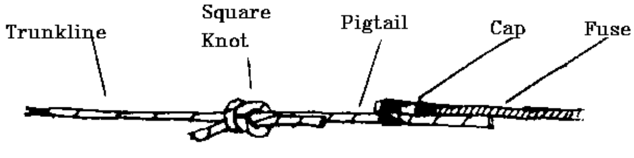


Fig. 50. Attaching Pigtail To Trunkline.

The main line of detonating cord which runs through the area where you have placed explosive charges is called a **"Trunkline"**. Lines of detonating cord run from this trunkline to the various individual charges as called, or **"Branchlines"**.

Notes:-

Priming with Detonating Cord

In a borehole, detonating cord will initiate every cap-sensitive cartridge which it contacts. However, it is nevertheless the practice to rig the first cartridge placed in the column as a primer. This adds certainty to the detonation of the entire column and also provides a means of withdrawing the explosives from the hole if this is necessary.

This provides not only a length of detonating cord running the full length or depth of the main charge.....which will fire all the cartridges it contacts.....but also a primer cartridge at the bottom. This all but eliminates the chance of a column of explosives failing to fire throughout its entire length.

The most common method of priming small diameter dynamite cartridges with detonating cord is to punch a deep hole in one end of the cartridge.....just as you do in end-priming with cap and fuse, but only a little deeper.....and insert the end of the detonating cord then, the cord is bent and passed back alongside the cartridge and taped there with plastic or electrician's tape, as shown below.

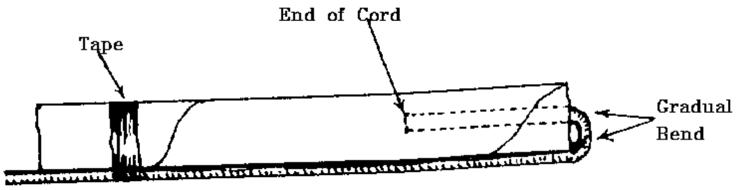


Fig. 51. Primed Small Diameter Cartridge Using Detonating Cord.

Another method is to punch a downward angled hole completely through the cartridge.....as in the **"Lacing Method".....**and lace the detonating cord through the cartridge, inserting the free end into a hole punched in the bottom of the cartridges, as shown below.

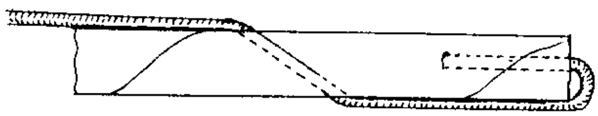


Fig. 52. Lacing Method For A Detonating Cord Primer Cartridge.

Taping is not usually necessary when this method of primer assembly is used.

Another method of **"Lacing"** which is not widely used commercially, but which provides excellent contact and strength is illustrated below. Four angled holes are punched through the cartridge.....the core laced through.....the end tucked under the loop is shown.....and the cord pulled taut.

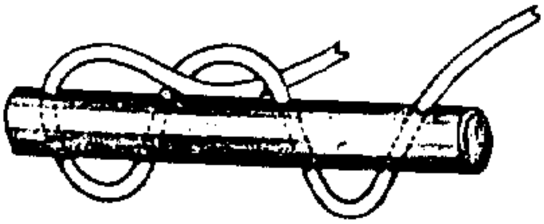


Fig. 53. Alternative "Lacing" Method.

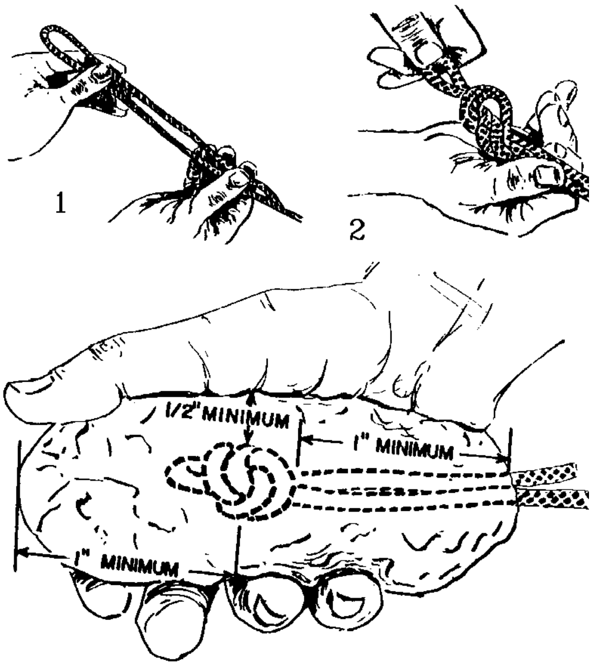


Fig. 54. Priming Plastique, Blasting Gelatin, etc., With Det Cord.

NOTES:-

Joining Detonating Cord

In preparing a detonating cord firing system, trunklines must often be extended.....branchlines must be tied in the trunkline.....and firing pigtails must be tied into the trunkline. This calls for tying knots in detonating cord.

Different types and grades of detonating cord are more flexible and easily tied than others. For connecting lengths of detonating cord.....such as in extending a trunkline system or attaching a capped pigtail.....the common square knot is recommended.

For connecting downlines to trunklines, a double-wrap half-hitch or **"Girth Hitch",** are most commonly used. If the cord is not sufficiently flexible to tie such a knot, we can form a clove-hitch in the trunkline.....slip the branchline through it.....pull the knot tight.....and tie an overhand knot at the end of the branchline to prevent it from pulling out.

These knots and the method of attaching a fuse blasting cap to two lines of detonating cord, are illustrated on the next page.

All knot connections must be tight, so as to provide intimate contact between the two pieces of cord and a high degree of strength. Plastic connectors are available to make connections in the grades of detonating cord which are difficult to tie.

All lines tied into a trunkline should be at right angles to it. If the downline or branchline slants back toward the point of initiation at an acute angle, it is possible that the detonation of the trunkline will sever or throw-off the downline before it is initiated.

Lets review some important fundamentals respecting the use of detonating cord.

1. It is initiated by one or preferably two blasting caps, either fuse or E.B. caps, taped in direct and intimate contact with the cord. These caps must be positioned at least six inches from the cut end of the cord, with the base of the caps pointing in the direction the detonating wave is to travel. It is recommended that the caps be attached to a short pigtail of detonating cord, which is not tied into the trunkline until you are ready to fire.

2. All knots must be tight.....so there is good contact.....and should be secure so as to resist coming apart if subjected to a strain. Lines tied into the trunkline should be at right angles to it and not slanted back at an angle toward the point of initiation.

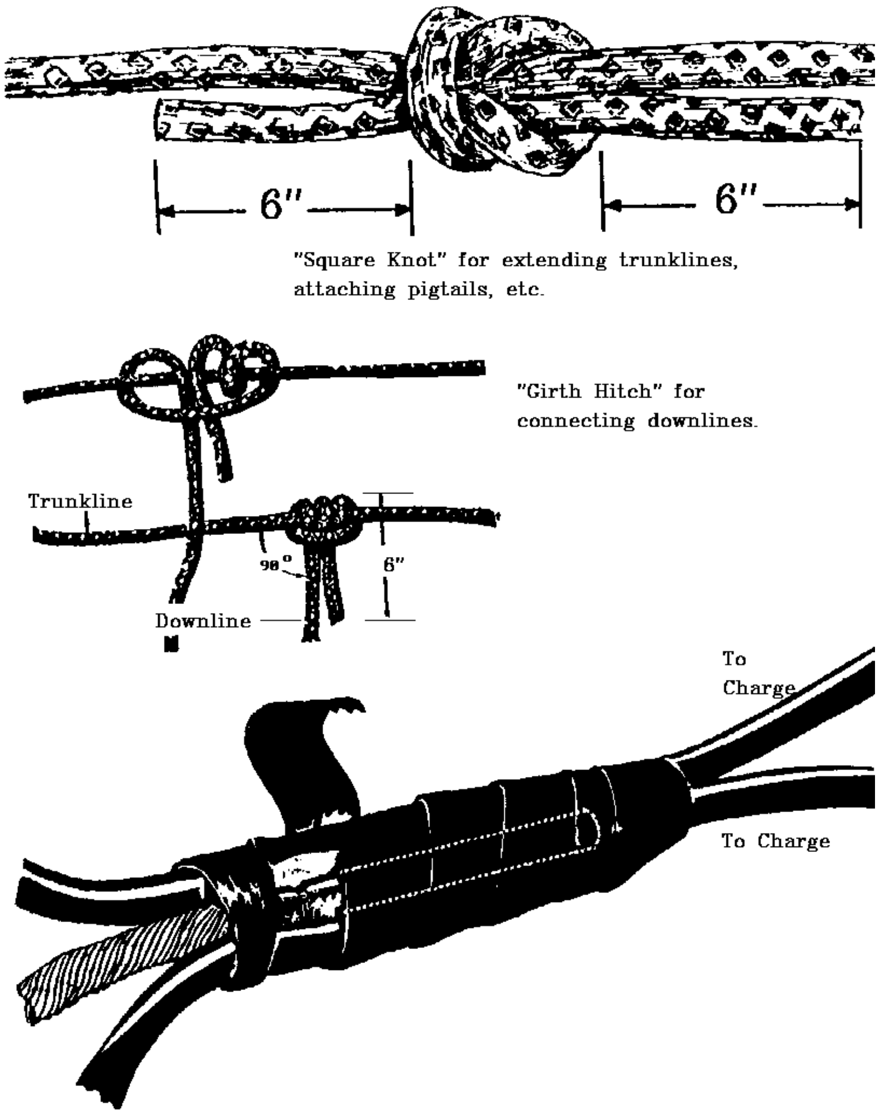


Fig. 55. Attaching Cap & Fuse To Detonating Cord, Along With Knots Used For This Purpose.

NOTES:-

Detonating Cord Firing Systems

For instantaneous firing, the thrunkline is unreeled so that it lies across the top of the holes to be fired. It should be reasonably slack to facilitate tying knots. The diagram below illustrates a single row of charges hooked up for instantaneous firing by blasting caps.

In the diagram below, we illustrate a hookup for firing two rows of charges. Note that the thrunkline forms a completely enclosed **"Circuit".** By doing this we minimize the chances of a misfire caused by a break in the trunkline, by providing two paths for the detonating wave.

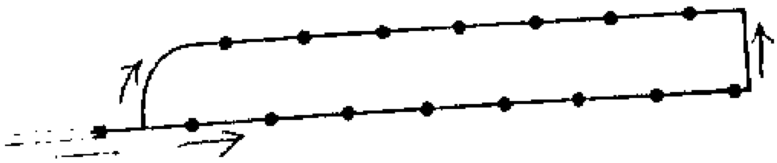


Fig. 56. A Single Row of Charges Hooked Up for Instantaneous Firing.

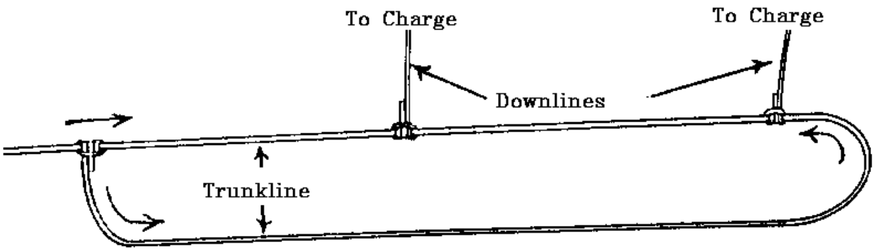


Fig. 57.   Detonating Cord Firing Circuit.

In the diagram which follows, we show three rows of charges connected by detonating cord for instantaneous firing. Again, note that these rows are joined by cross-ties so there will be a complete circuit and two detonating waves traveling in two directions around it. An undetected break in trunkline would not result in a misfire.

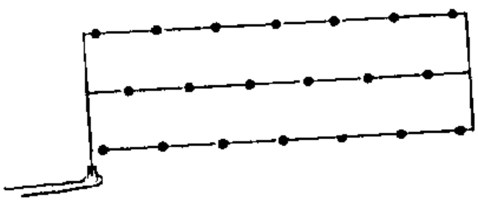


Fig. 58. Three-Rows of Charges Connected By Detonating Cord for Instantaneous Firing.

Chapter V

Propagation Firing

There is a technique for firing a number of charges simultaneously other than by individual priming and firing each. This is called **"Propagation Firing"**.

As you know, High Explosives are detonated by a shock wave, which is usually provided by a blasting cap. Usually, each charge has its own cap and primer cartridge.

Below, we illustrate the progress of detonation through a cartridge or column of explosives. Note the shock wave which is formed, and how it moves through the explosives.

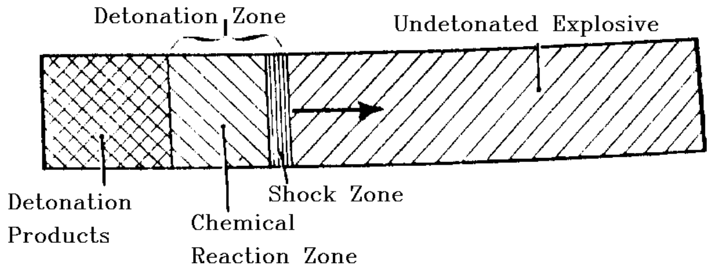


Fig. 59. Shock Wave as it Detonates Through An Explosive Charge.

After the explosive is consumed, the shock wave continues to move outward at high velocity. If another explosive is nearby, it may be detonated "Sympathetically" or by "Propagation" by this traveling shock wave.

A number of unconnected and unprimed explosives may be made to explode almost simultaneously if they are in close proximity to each other, with only one of these being primed and fired by a cap. The shock wave travels from charge to charge, detonating each in turn in a chain-like reaction.

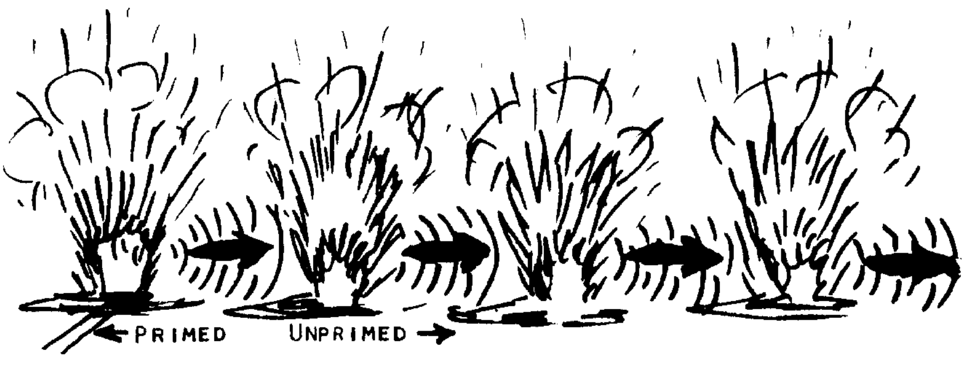


Fig. 60. Propagation Firing & the Explosive Traveling From Cartridge to Cartridge.

The Propagation Method of firing is often used in ditch and pond blasting, excavation work and other operations which call for explosives to be placed in close proximity and where it is practical to use one of the more sensitive explosives. Certain other conditions must also be satisfactory.

The method is safer in most respects, since the handling of sensitive blasting caps and primers is greatly reduced and the one primed charge is left until just before firing. This makes it unnecessary to work around numbers of primed charges during loading.

And, from the standpoint of economy, the cost of caps, fuse, wire and labor in priming and loading, may be reduced greatly.

The material or soil in which the charges are to be fired is critical in determining whether or not propagation firing can be employed. Wet or very damp muck-type soil or water-covered areas provide the best conditions for propagation firing. A good rule of thumb for finding out whether soil is sufficiently wet is to squeeze a hand-full. If it packs, hold its shape and can be molded, it is probably wet enough. If water can be squeezed from it or the surface or shotholes fill with water, so much the better.

If you squeeze the soil and it continues to flow or run from your hand such as is the case with dry or sandy soil, it is doubtful if propagation would occur within practical distances. The ease and economy of this method are such, however, that it sometimes pays to wait until a time of the year when you know the ground will be wet. For example, if you were going to blast a drainage ditch or a farm pond you might schedule the job for a season when you knew that ground conditions would be suitable for propagation firing.

Before proceeding with propagation firing you should first fire a few test shots to insure that conditions are right and determine how closely the charges should be set.

It is a common practice to double the quantity of explosives used in the primed hole. This is the **"Spark Plug"** which initiates the chain-reaction and the propagating wave. It is also a good idea to prime more than one shothole if a large number of charges are involved. For example, if you were blasting a long ditch by this method you might simultaneously fire one charge at each end of the line of unconnected holes.

It is important for the blaster to understand propagation firing not only so he/she can take advantage of this method, but also so he/she can guard against propagation when he/she doesn't want it! Obviously, if you wish to fire a number of charges in sequence or rotation.....and these charges may contain sensitive explosives and are closely spaced.....you may get **Unwanted Propagation** All the charges could detonate simultaneously by propagation, unless you took steps to prevent this.

Because, a detonating wave is transmitted so efficiently through water, persons engaged in underwater blasting must be especially alert to guard against propagation firing if they wish to avoid the simultaneous detonation of multiple underwater charges.

The maximum distance at which charges can be placed and detonated with certainty by propagation depends upon the number of factors, including the sensitiveness of the explosive involved. The quantity of explosives in the initiating charge and other charges, the degree of confinement, soil characteristics and moisture content and others. Generally speaking, however, smaller charges or shotholes are not more than twelve to twenty-four inches apart in wet earth.

Test-shooting is strongly recommended before loading for propagation firing.

When propagation charges are spaced at the greater distances in soil, keep in mind that a boulder, log or similar obstruction between charges may slow, block, or deflect the propagation wave, and bring the chain-reaction to an end. And, keep in mind that a detonation wave loses its strength very quickly in the air and in loose dry materials.

Chapter VI

Firing Multiple Charges in Rotation

In many blasting operations multiple charges are not fired simultaneously, but rather in sequence, with precise delay periods between the detonation of the individual charges in the round.

There are a number of reasons why delay firing in rotation may be necessary or desirable. It may be done to reduce ground vibration. Ten charges exploding at the same instant will cause much more ground movement than the same ten charges each fired an instant apart. This may be a very important consideration when blasting in built-up areas to prevent damage to nearby buildings and utilities and some communities prohibit blasting vibrations in excess of certain limits and/or limit the quantity of explosives which can be detonated at one time.

Delay firing also frequently improves fragmentation, reduces **"Back Break"** or **"Over Break"**, and reduces the amount of explosives needed to do the job. Unfortunately, it does not appreciably reduce the blasting noise, because the sounds of the individual blasts tends to blend together.

There is another important reason why we often fire charges in a precise delayed sequence. If you were digging a large hole in the ground or into the side of a steep hill with a shovel, you would probably dig a smaller hole first, and keep enlarging that hole by doing this you provide a space for the dirt to fall as you make the hole bigger, and the dirt falls away from the sides of the smaller hole with much less effort than would be required if you hadn't dug the **"Starter Hole".**

We often do the same thing when we are blasting. We arrange the charges to fire in such a manner that the first group cut a small hole or wedge from the excavation or tunnel. Then, charges immediately surrounding this first hole are timed to explode.....and so on outwards until the hole, shaft or tunnel is the diameter we want. By doing this we systematically provide a space into which the dirt or broken rock from successive blasts can move.....just as you do when digging with a shovel.

We can do this almost automatically through the use of delay-firing electric blasting caps, detonating cord delay-firing connectors or igniter cord. Once we have properly primed and hooked-up each charge, we need only to initiate the action and each charge will then be fired automatically in the proper sequence with the desired delay intervals.

NOTES:-

Here are two simple illustrations. In the first, you are looking down at a cliff face. You wish to collapse the face, such as you might in a quarrying operation. Three rows of charges have been placed and each row will be fired in the sequence indicated by the numbers **"1", "2",** and **"3".**

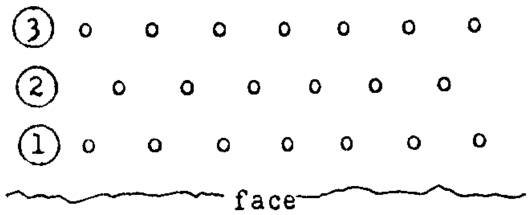


Fig. 61. Firing Multiple Charges in Rotation. i.e.:- "Cliff Face".

In the illustration below, you are looking toward a vertical face. Charges marked **"1"** have been placed in holes drilled at an angle to form a wedge or **"Horizontal Cut"**. These fire first, and the wedge or "Cut" is blown out. The charges **"2"** detonate an instant later. The debris from their explosion can now more freely move than would have been the case if the first cut had not been made. An instant later, charges marked **"3"** fire. Rock fragments from these would by then also be able to move more freely and in more directions.

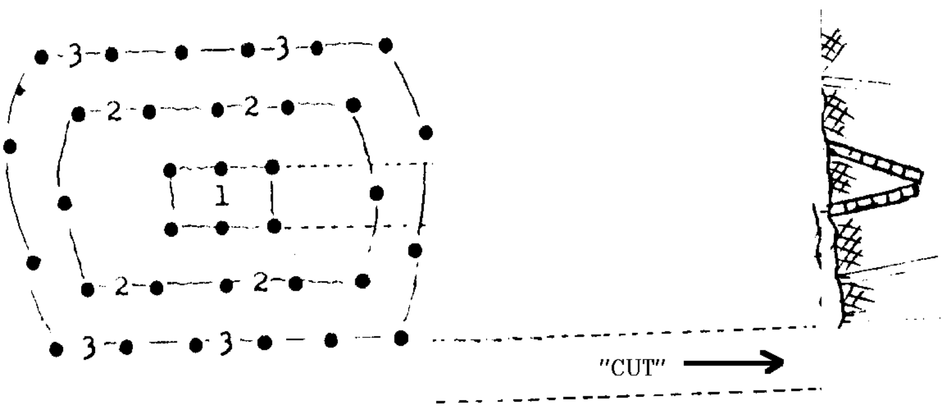


Fig. 62. Firing Multiple Charges in Rotation. i.e. "A Vertical Face".

Each series of charges have made it easier for the charges which follow to do their job efficiently. The material has been removed in logical steps, and fragmentation has been improved and power saved.

Delay firing is divided into two types.....short-interval or millisecond delay firing.....and long-interval delay firing. The former is used mostly when charges are relatively closely spaced in small diameter shot holes, such as in rock excavation and some quarrying. The delay intervals are as short as 25 milliseconds.....or 25/1,000th of a second.

Long-interval delay firing is often used where charges are larger and in large diameter drillholes spaced further apart, and in certain mining operations for sinking shafts, driving tunnels, etc. Unlike short-interval delay firing where excessive ground movement between successive shots is intentionally avoided, long-interval delay firing periods are intended to provide an opportunity for considerable rock movement between successive detonations.

By way of comparison, fifteen charges fired in a long-interval delay series would detonate over a time span of twelve seconds. Fifteen charges can be fired in a short-interval [Millisecond] delay series in as little as one-half second! Fifteen charges can be fired rotationally with detonating cord and delay connectors in as little as one fourteenth of a second.

It should be noted that cut-offs caused by ground movement are more common when firing in delay series than when firing multiple charges instantaneously, and may be especially troublesome when blasting seamy or badly fractured material. And, cut-offs are more common when the delay firing devices are on or near the surface where movement will be the greatest. Accordingly, when delay firing with electric caps, the primer cartridge should be at or near the bottom of the column, and when using detonating cord with delay connections very short intervals should be used.

Notes:-

Rotational Delay Firing With Cap and Fuse

When working with cap and fuse, we achieve rotational delay firing by one of two methods. Either by **"Trimming Fuse"** or through the use of **"Igniter Cord".**

There are important rules to follow when firing multiple charges in rotation with cap and fuse. First, the primer cartridge should always be located near the bottom of the borehole. Second, the timing of the round should be such that all fuses in the round have burned down below the collar of the borehole before the first charge explodes, to prevent one explosion cutting off the fuses leading to unfired charges. And, thirdly, men who are lighting numerous fuses for rotational firing must guard against becoming to absorbed in their job that they fail to remain alert to the passing of time.

In the latter respect, it is a good idea to make an "Alarm" with a blasting cap and a length of fuse, which is one-half the length of the shortest fuse being used. This is buried just far enough under the dirt to prevent flying fragments, and is the first fuse lit. It will detonate before any of the charges are ready to explode and warn all persons lighting fuses to leave the area immediately and seek cover.....whether or not they have finished their jobs.

"Trimming" consists of cutting different lengths of fuse from the fuse ends which protrude from boreholes, after the charges have been loaded and stemmed. The order of firing is obtained by this trimming and by lighting the fuses in the order you want the charges to fire.

In actual trimming operation, a good rule of thumb is to trim at least one-half [1/2"] inch of fuse for each foot of fuse length. For example, let's suppose you have 36 inches of fuse in each borehole to start with. You would leave this fuse intact on the last hole you want to fire. On the charge you wanted to fire second-to-last you would trim about 1 1/2 inches off.....on the charge you wanted to fire third-from-last, you would trim about three [3"] inches.....on the charge you wanted to fire fourth-from-last you would trim 4 1/2 inches.....and so on.

Under NO Circumstances, should a fuse be trimmed to a point where there is less than 24 inches protruding from the collar of the borehole! Some Provinces require a minimum of 6 feet, and also might limit the number of fuses which one man is permitted to light in any one round.

Trimming should be done with sharp, clean cap-crimpers. Fuses should be lighted in the order you wish the charges to explode. And no attempt should be made to light these fuses by match.....**Hot-Wire fuse lighters** should be used to add speed and certainty to the lighting operation.

Rotational firing with cap and fuse can also be accomplished through the use of **"Igniter Cord"**.....such as made by Ensign-Bickford and marketed as **"Igniter Cord" In Canada, it is still igniter cord but referred to as "Thermalite Igniter Cord".** We consider this to be the safer and more precise method.

"Igniter Cord" is a thin wire-bound fuse about 1/16th of an inch in diameter, with a core of thermite which burns with a very hot external flame. It is available in a choice of three burning speeds here in Canada.....**Fast, Medium and Slow**. It is marked at one foot intervals. The burning speeds are consistent and are marked upon the individual packages that they come in.

When using igniter cord for multiple shot rotational firing, trimming is unnecessary. All fuses are cut to identical lengths. Then, the igniter cord is run from fuse to fuse in the order to be fired. Knowing the burning speed of the cord, the blaster is able to fairly accurately regulate the delay period between charges by regulating the length of igniter cord running between these charges. The cord is speedily attached to the safety fuse ends by means of special connectors which are illustrated below. Only the igniter cord must be ignited.....and this at just one point.

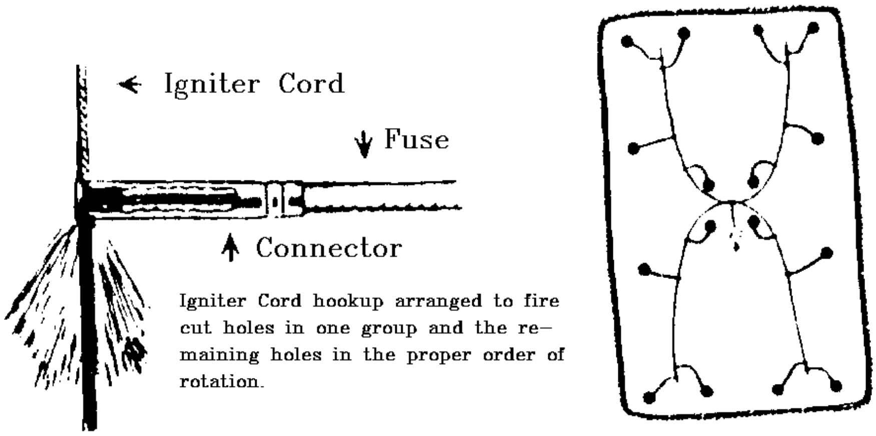


Fig. 63. Rotational Firing with Igniter Cord.

Notes:-

Firing Multiple Charges Simultaneously with Cap and Fuse

In **"Secondary Blasting".**....That is breaking up large fragments produced by a primary blast into smaller pieces.....we often wish to blast a number of rock or fragments more or less simultaneously.

We can achieve almost simultaneous detonation of all charges in a round through the use of a product called **"Quarry Cord"**. This is designed to automatically ignite a series of fuses as rapidly as possible. Like **"Igniter Cord", "Quarry Cord"** burns with a very hot external flame. However, it burns much faster.....at 1 to 1 1/2 feet per second.

"Quarry Cord" is attached to the ends of all safety fuses in the round.....which have all been cut to identical lengths.....by special connectors. They are joined in a manner so that the flame will ignite all the fuses in the shortest possible time. The cord can be joined to itself to provide cross-connections which speed up the ignition of all fuses in the round, as shows at point **"B"** and **"C"** in the drawing below. The Quarry Cord is ignited at point **"A".**

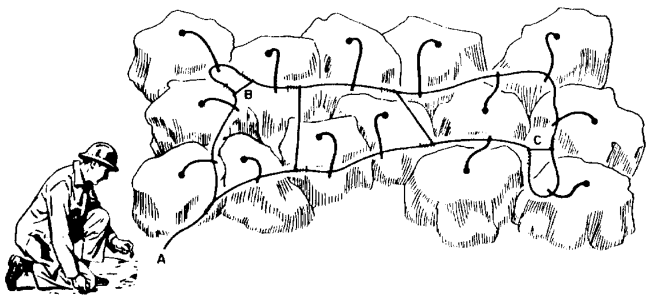


Fig. 64. Firing Multiple Charges Simultaneously with Cap and Fuse

While trimming is still a common practice for rotational firing with cap and fuse.....and some blasters attempt to fire multiple charges simultaneously by lighting numerous fuses as quickly as possible.....We strongly recommend the use of igniter cords such as **"Igniter Cord"** and **"Quarrycord"** for rotational and simultaneous firing with multiple charges with cap and fuse.

A word of caution, however. Use these igniter cords only for the purpose for which they were intended! Never use fast-burning "Quarry Cord" for the simultaneous firing of multiple charges. Always test burn a six-foot length of any type of fuse to determine its burning rate and to positively identify it!

Notes:-

Electric Delay Firing

Both long and short-Interval delay firing can be readily accomplished with delay-firing electric blasting caps. Delay-firing E.B. caps are manufactured by inserting a delay column of powder between the ignition mixture and the primer charge, which serves as a time fuse.

Delay caps may be purchased in series.....numbered as to their firing order or sequence. These are assembled into primer cartridges and the cartridges loaded into charges in order to be fired. Then, one application of electric current and the entire series of charges will be detonated in the pre-determined firing order.

For the purposes of illustration we will consider DuPont delay electric blasting caps. These are available in both long and short-interval delay series. They call their short-interval series **"Millisecond [MS] Delay E.B. Caps", and these are available in 19 delay intervals.....the shortest of which is 25 MS.....25 Milliseconds or 25/1,000th of a second.....and the longest is one second**. These are identified as to delay period by designations such as **"MS-50"** and **"MS-300"**. The first indicates a **50 millisecond delay element**.....the second a **300 MS Delay element**. These caps are also numbered in firing order or sequence in the series.

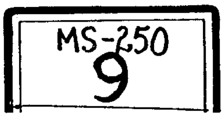


Fig. 65. Delay-Firing Electric Blasting Cap, Tag.

The above tag indicates that the cap to which it is attached has a 250 Millisecond delay.....one quarter of a second.....and will be the 9th in the series in firing order.

Let's illustrate how you might select the delay caps for short-interval delay firing. You want to shoot three holes in sequence. The first could be detonated by an instantaneous cap. The second could be primed with an MS-25, and the third with an MS-50. The first charge would be fired instantly.....the second 25 milliseconds later.....and the third would fire 25 milliseconds after that if you wished a slightly lower delay interval between the three detonations you might place an MS-100 in the second hole, and an MS-200 in the third. This would give you one-tenth one-tenth of a second between detonations. Or, if you wanted an even longer delay, you could use an instantaneous cap in the first.....an MS-500 in the second.....and an MS-1000 in the third, which would give a one-half second delay between shots.

Longer delay intervals can be obtained by using caps such as DuPont markets as **"Acudet Mark V Delays" and Atlas as "Atlas Timemasters".** In the DuPont series these caps are numbered only as to firing order.....**The tags DO NOT indicate the delay period**, which runs from period "0" which has a 25 Millisecond delay, through to period "14" which has a 12 second delay.

Generally speaking, long-interval delay firing does not provide as good fragmentation or economy as short-interval firing.....and can cause more misfires, especially if the holes are too closely spaced.

Delay Firing With Detonating Cord

Delay firing with detonating cord is a little more complicated than with delay E.B. caps, but still not difficult. It is highly recommended for many blasting situations, especially where the danger of extraneous electricity makes electric blasting hazardous.

The cut-off problem can be especially troublesome when delay firing with detonating cord, unless you know what you are doing. This is because delay-timing is achieved through connections which are located on the surface.....in the blast area.....not at the bottom of a drill hole. Obviously, components lying on the surface in the blast area are exposed to damage by blast, ground movement and flying debris.

Generally speaking, the greater the time-lapse between the firing of nearby holes, the greater chance of a misfire. So, the solution to the cut-off problem when using detonating cord seems to be to use very short interval delays. The shorter the distance between charges, the shorter the delay interval which should be used.

A good rule is not to exceed 1/1,000th of a second delay for each foot of spacing between shotholes. For example, if drill holes are spaced on ten-foot centers, a delay of ten milliseconds or less.....preferably less.....would be desirable. If the holes were 15 feet apart, a delay period of 15 milliseconds or less would be desirable. And, if the material being blasted is seamy or badly broken, the delay interval should be further reduced.

The safest and most efficient method of delay firing with detonating cord is through the use of **"Millisecond Delay Connectors"** inserted in the trunkline just before the downline leading to the hole to be delayed. These connectors are a molded plastic sleeve fashioned so that detonating cord can be looped and locked into place with a tapered pin at each end. They contain a copper tube delay element in the center. The connector is a delay timing mechanism which interrupts the normal speed of detonation of the trunkline by a specific amount of time.

Fig. 66. MS Delay Connectors.

MS delay connectors contain sensitive explosives and should be protected from heavy impact, flame, excessive heat and sparks. Connectors should not be introduced into the firing system until just before blasting, and if located in an area, where they may be exposed to falling rocks, they should be covered with sandbags.

MS connectors are available in four delay intervals only.....each identifiable by the color of the plastic.

The shorter intervals.....MS-5's and MS-9's.....are most often used in systems involving small diameter boreholes on close spacings, while the longer interval MS-17's and 25's are most often used with large diameter shotholes on wide spacings.

Don't assume that just because only these four delay periods are available that you don't have a wide choice of delay periods. If you want a 14 millisecond delay you can insert one MS-5 and one MS-9 into the cord.....if you want a 10 MS delay you can insert two MS-5's.....etc.

The most common and efficient method of delay firing is to run your trunkline from charge to charge, in the order that you want the charges to fire. When running the trunkline, leave ample slack at each shothole, because you're going to have to cut the line there and attach the MS connectors. Just before blast time cut the trunkline at the desired locations.....where you want to introduce the delays.....and attach the connectors. This is done by bending each end of the cut cord into a "U" about six inches from the ends. Insert these loops into the connector and secure them with the tapered pins which are press-fitted into the holes in the sleeves. Be sure each end of the cord contacts the copper tube inside the sleeve!

The connectors should be located as close as possible to the hole they are delaying, where they are at least likely to be disturbed by the hole firing previously.

Below, we show a very simple detonating cord delay firing system. Connectors are located at points marked **"X"**. It will be seen that if each of these connectors was an MS-9, the holes would be progressively fired with a 9 millisecond delay between each.

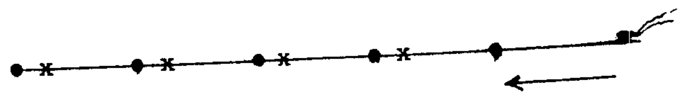


Fig. 67. Simple Detonating Cord Delay Firing System.

In single line blasts, however, double trunklines are recommended whenever practical, as illustrated below. This is to provide an alternate route so the detonating wave can reach each charge from two or more directions, thereby reducing the chances of a misfire caused by a break in the detonating cord trunkline. This is good, and especially valuable when delay firing.

In multiple-row blasts, double trunklines are not necessary. Instead, cross-ties should always be used to provide an alternate route for the detonation wave. These cross-ties will be seen in the patterns shown below.

Many different delay layouts can be designed. In the illustration below, two rows of holes are hooked up to the trunkline using cross-ties, with the MS Connectors situated on the cross-ties at the points marked **"X"**. The first row of holes will be fired instantaneously, the second is delayed for the delay period of the connectors used.

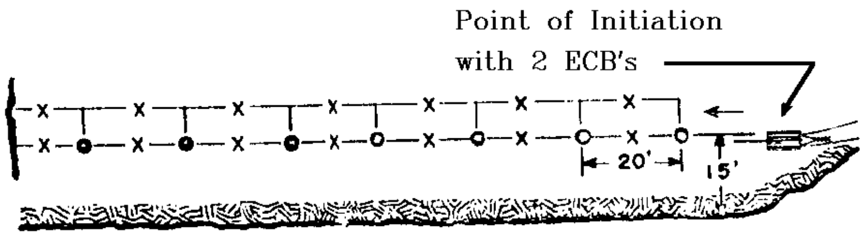


Fig. 68.A Single-Row, Double Trunkline

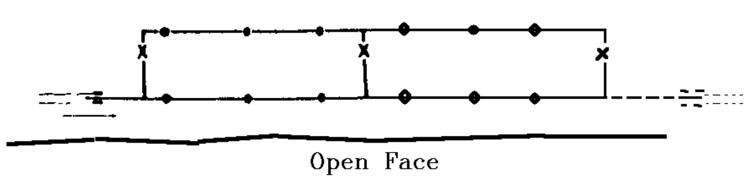


Fig. 69. Multiple Row Blasts on an Open Face.

And below, we show a similar three-row shot, with each row being fired in delay sequence.

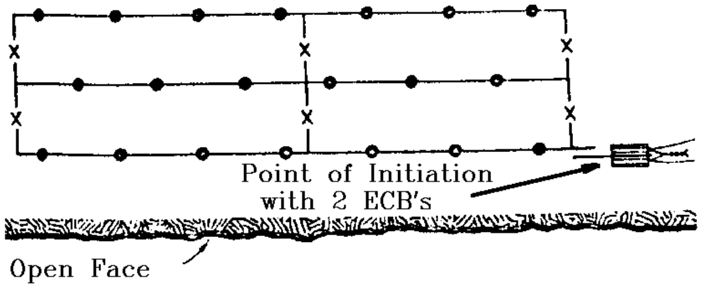


Fig. 70. Multiple-Row Blasts.

In the illustration below, three rows of holes are hooked up with connectors indicated by **"X".** The end hole in the first row fires instantaneously, and the other holes are progressively fired as indicated.

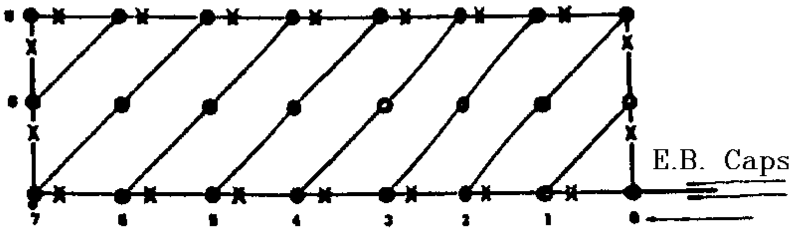


FIG. 71 Three-Rows of Holes are Hooked-up with Connectors.

You will observe that this design fires the charges in diagonal rows from right to left.

Below, three rows of holes are set up to fire in rotation, making first a **"CUT",** and then progressively enlarging this. The center two holes are fired instantaneously, and the other holes are fired in progression as numbered.

[YOU ARE LOOKING DOWN, AT A VERTICAL FACE.]

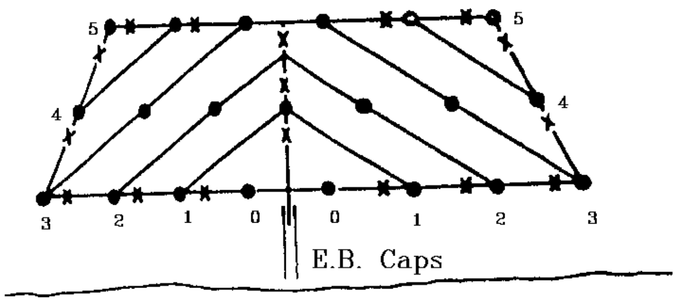


Fig. 72. Three-rows of Holes are Set-up to Fire in Rotation.

There is an almost limitless variety of layouts and delay systems which can be achieved with detonating cord and delay connectors.

NOTES:-

Chapter VII

Explosives

Nitroglycerin

While you will not likely be dealing directly with pure nitroglycerin in blasting operations, you should have an understanding of this product because it is an ingredient found in most commercial explosives, and may **"Bleed"** or leak from explosives which have been improperly stored and have deteriorated. Also, nitroglycerin's are sometimes used by specialists in gas and oil-well shooting and for fracturing especially hard rock formations.

Nitroglycerin is an oily liquid which is colorless when pure, but turns a yellowish-brown when impure. It can explode from such causes as overheating, a slight jar, chemical reaction with container materials, impurities forming in it during storage.

And for no apparent reason at all!

Because it is so sensitive, nitroglycerin cannot legally be used or shipped in its pure form. It is an extremely powerful explosive, **with a detonating rate of approximately 29,000 to 30,000 feet per second**.

Desensitized nitroglycerin.....liquid or solidified.....is available commercially for special operations where an exceptionally high degree of formation fracturing is desired.

You will appreciate the hazards when nitroglycerin leaks from explosives and lays or soaks into a magazine floor! Obviously, the best defense is to take the simple steps which are necessary to manage the explosives magazine properly and thereby prevent explosives from deteriorating and creating this unnecessary danger. But, you should also know how to deal with nitroglycerin which has leaked from explosives.

First, don't handle or use explosives which show evidence of leakage. Contact your supplier immediately with regard to disposing of such stock. Second, make a determination then and there to prevent similar problems in the future by following recommended storage practices in an approved, well ventilated magazine! Deteriorated explosives are invariably the result of poor storage facilities or poor magazine management.

You may be confronted by a liquid which you suspect may be nitroglycerin.....but you are not sure.....you can test for nitro by cutting a strip of newspaper about one-quarter of an inch wide and eight or ten inches long. Saturate about three quarters of an inch of one end of this strip in the suspected liquid. Then, in a safe place.....away from the magazine and other explosives.....**Light the dry end of the strip and back off a few yards**. If the liquid is nitroglycerin it may explode with a sharp crack, but more likely it will burn briskly with a bright yellow or greenish flame and give off a crackling sound.

When you find nitroglycerin on the floor of a magazine, it must be decomposed, or neutralized, as soon as possible. To make a solution to do this, mix

1 1/2 quarts of water

3 1/2 quarts of denatured alcohol

1 quart of acetone and

1 pound commercial grade, 60% sodium sulfide.

Dissolve the sodium sulfide in the water adding the alcohol and acetone.

The nitroglycerin destroyer doesn't keep well. So have the necessary ingredients on hand and mix up the solution as you need it. Or, if the solution must be stored it is a good practice to have the water and sodium sulfide mixed in one container, **[Solution "A"]** and the alcohol and acetone mixed in another container **[Solution "B"]**. When you need the destroyer, mix the two solutions together.

Dilute any nitroglycerin liquid laying on the surface by pouring on liberal quantities of the destroyer solution. The we absorb the desensitized solution with dry sawdust. This is swept up and taken some distance from the magazine and burned. Then, any remainder or nitroglycerin stains in the floor should be doused with nitroglycerin destroyer/remover, and after a few seconds thoroughly scrubbed with a stiff brush. Again, the desensitized solution is then absorbed in dry sawdust and removed.

Keep in mind that skin contact with nitroglycerin can have a toxic effect!

This can be in the form of:-

1. **A moderate to severe headache. e.g.:- Vassal headache caused by the blood vessels and arteries expanding in a person's head. This takes from 3 to 24 hours to dissipate.**
2. **A rapid heart rate. If the person who has skin contact with nitroglycerin, has an un-diagnosed heart condition, this can be very dangerous and can bring on a heart attack or a stroke.**

Some people nitroglycerin has no effect upon, but others it effects quite badly with Nitro-Headaches.

Be cautious, as nitroglycerin can be very dangerous and is easily absorbed through the skin.

<u>NOTES:</u>

Straight Dynamite

"Straight Dynamite".....sometimes also called **"Nitroglycerin Dynamite"**.....is the most direct descendant of Nobel's original dynamite. You will recall that Nobel mixed nitro with a chemically inert earth called **"Kieselghur"**. Today's straight dynamite still relies upon nitroglycerin as the only explosive ingredient. However, it now contains flammable absorbent materials such as wood pulp, starch and other such ingredients which contribute to the total energy output. Additionally, other ingredients have been added to improve dynamite, including additives to neutralize the formation of acids during storage, nitrated glycol to prevent freezing and sodium nitrate as an oxidizer.

Straight or nitroglycerin dynamites now contain such mixtures as nitroglycerin.....the explosive; sodium nitrate.....the oxidizer; and a combustible absorbent, such as wood meal [wood pulp or saw dust].

We have already described the grading of nitroglycerin dynamites as to strength, velocity and density. These high velocity straight dynamites give a quick, shattering action. Velocities run from about 11,000 to 19,000 feet per second. The most popular size is the 1 1/4 by 8-inch cartridge and the most popular strength is in the 50 - 60% grades. The cartridge count per 50-pound case varies from about 102 - 106 cartridges per case.

Generally speaking, straight nitroglycerin dynamites have good water resistance qualities, especially in the higher grades. However, the fumes generated by the detonation of the nitroglycerin dynamites are classified from **"Poor" to Very Poor"** and these products are therefore generally unsuited for use underground or in other confined areas.

High strength dynamites are seldom used for general construction blasting today, for a number of reasons. They are more expensive than most other types. They are considerably more sensitive to accidental detonation by shock, and therefore more dangerous to handle and use. And the have poor fume qualities, generating more toxic gases than most other commercial explosives.

Straight nitroglycerin dynamites are used in those situations where a strong high velocity explosive is needed.....on jobs such as shattering hard rock formations or cutting steel.....and in blasting by the propagation method where a highly sensitive explosive must be used. It is also selected on occasion because of its water resistant properties.

During recent years the trend has definitely been away from the straight nitroglycerin dynamites, to the safer and more economical **"Ammonia Dynamites".**

NOTES:-

Ammonia Dynamite

The dynamite most commonly used today in general blasting is known as **"Ammonia Dynamite"**, and sometimes referred to as **"Extra Dynamite"**.

While straight dynamites contain nitroglycerin as the only explosive substance, ammonia dynamites also contain ammonia nitrate as an explosive. The terms **"Ammonia" and "Extra"** both refer to the addition of this extra ingredient.

In the manufacture of ammonia dynamite, much of the nitroglycerin and some of the sodium nitrate and wood meal are removed and replaced with ammonia nitrate. Almost all ammonia dynamites still contain some nitroglycerin to serve as a sensitizer. **Ammonia nitrate is only about 70% as strong as nitroglycerin**, and has the added disadvantage of absorbing moisture. On the other hand, it is much less costly to manufacture and safer to use. **Ammonia dynamites are more economical than nitroglycerin dynamites per unit of energy.**

In their action, they tend to have lower velocities than straight dynamites, and are therefore more suitable for those blasting operations where a **"Heaving"** rather than **"Shattering"** action is desired. Extra dynamites are made in high strength, low velocity grades which are not available in straight dynamites, and such products are more desirable for blasting softer materials and use in operations where high strength is desirable, but a high degree of fragmentation is unnecessary or undesirable.

Ammonia Dynamites tend to be less dense, more **"Bulky"** than N.G. dynamites. This too is a desirable feature in many blasting operations.

It can be misleading to generalize too much about the relative characteristics of ammonia and straight dynamites, because the former are made with varying percentages of nitroglycerin, and you may have a straight dynamite in the lower velocity and density which has characteristics very similar to one of the higher velocity, denser grades of ammonia dynamite.

Ammonia dynamites are available in a wide choice of strengths, velocities and densities.....suitable for the vast majority of blasting jobs. They are unsuitable only for those jobs which demand a highly sensitive, high velocity or highly resistant explosive.

You will recall that the **"Strength"** of ammonia dynamite is indicated by the percentage figure and that this indicates the strength of straight dynamite the product is comparable to. An ammonia dynamite graded **"50% weight strength"** has the same strength as a 50% straight dynamite by weight.

NOTES:-

Gelatins

"Blasting Gelatin" and **"Gelatin Dynamite"** were invented by Nobel in 1875, and are made **by colloiding Nitro-Cellulose with Nitroglycerin**, both of which are very powerful high explosives.

As in the case with other dynamites, gelatin dynamites are available in two forms.....what may be called **"Straight Gelatins"**, in which nitroglycerin and nitrocellulose are the only explosive ingredients.....and **"Ammonia Gelatins"**, in which some of the nitroglycerin has been replaced by ammonia nitrate. These are also called **"Special Gelatins"**.

Just as in the case of **"Straight"** and **"Ammonia"** dynamites, replacing some of the nitroglycerin with ammonia nitrate produces an explosive which is less sensitive and of lower velocity.

"Straight Gelatins" vary in strength from, although there is a **"100% Gelatin"** which is essentially nitroglycerin with just enough nitrocellulose added to turn it into a rubbery mass.

AS the name implies, gelatins are gelatin-like, rubbery and plastic in consistency. They are very dense and highly water resistant.

Velocities of the straight gelatins vary from a low or about 10,000 feet per second to a high of over 26,000 FPS These high velocities make the product especially suited for such jobs as blasting in extremely hard rock formations, cutting steel, deep-well shooting and other projects where maximum fracturing and loading density is called for. Because of its excellent water resistance and other characteristics it is ideal for many underwater operations such as salvage jobs where steel is to be cut. It is also suitable for situations where an explosive will be exposed in a wet shothole for long period of time before firing.

Straight gelatin dynamites are relatively costly and consequently are not widely used for general blasting. Their use is generally restricted to those operations which demand an explosive having their special properties. Also, they are highly flammable.

Some blasters keep a case of **60% gelatin dynamite** on hand because of its usefulness in making primers for insensitive explosives or loading in the bottom of wet boreholes.....shattering exceptionally hard rock.....cutting steel.....or handling those other small jobs or situations where a plastic, high velocity, dense or highly water resistant explosive is needed.

"Ammonia Gelatin Dynamite" or **"Special Gelatin"** as it is sometimes called.....derives a portion of its power from ammonium nitrate, which replaces some of the nitro. These products retain most of the gelatinous and other characteristics of the straight gelatins, but are somewhat lower in velocity and slightly less water resistant. They are considerably less expensive than straight gelatin and are used economically in many mining, quarrying and construction activities in which the use of a dense, fast, water resistant explosive is advantageous.

There are also **"Semi-Gelatin Dynamites"**, which are basically ammonia dynamite containing some gelatinized nitroglycerin to provide greater water resistance and cohesiveness. These are even more economical and are widely used in projects where an explosive is needed which has some of the qualities of a gelatin, but more of the **"Heaving"** or **"Lifting"** action of an ammonia dynamite.

Data concerning explosive products is readily available from the manufacturer or dealer.

Notes:-

Blasting Agents and Cap-Insensitive Explosives

During recent years there has been an increasingly widespread use of "Blasting Agents". Especially in those many industries and operations in which large shots and large diameter drill holes are utilized.

Commercial blasting agents are chemical compositions or mixtures which contain no ingredients classified as an explosive, but can be made to detonate under certain favorable conditions.

If you take ordinary fertilizer grade ammonium nitrate.....mix it with a fuel such as common fuel oil.....properly confine it and prime it with a cap and high explosive primer.....it will detonate at velocities of up to 14,000 feet per second! Yet this is chemically NOT an explosive, but an oxidizing agent.

Ammonium Nitrates .....which are classified as **"Oxidizers"** rather than **"Explosives"**.....have an explosive strength which is comparable to a 60% straight dynamite when mixed, loaded and fired under optimum conditions.

Such blasting agents offer many advantages. These are products capable of high performance, yet which cannot be intentionally or accidentally detonated by the strongest commercial blasting cap, or by detonating cord. Blasting agents cannot be fired by heat, shock, friction or impact. They are much cheaper than high explosives and their use has resulted in tremendous economies in some industries.

Blasting agents are not generally classified as explosives in so far as shipping is concerned and conditions of storage are usually much less strict than is the case with the storage of high explosives.

In addition to safety and economy, other important merits of blasting agents include their non-freezing nature, the fact that they are non-headache producing, that they are available in a wide range of forms from free-running pellets to sealed in waterproof containers and some have good water resistance.

Pourable **"Free-running"** blasting agents are often used to supplement cartridged high explosives, especially in large diameter shotholes. After the column has been loaded with cartridges, blasting agents are poured in to fill the spaces between the cartridges and the wall of the hole, thereby improving confinement, increasing loading density, adding power and improving column-propagation.

Free running blasting agents are also used without cartridged explosives. Because of their free-running form they can completely fill all spaces within a borehole, which is usually impossible to achieve with cartridged explosives.

It will be seen that under many circumstances much time and labor can be saved through the use of free-running blasting agents, in addition to the low material cost.

The most basic and lowest cost blasting agent is probably **"ANFO"** which detonates ammonium nitrate fuel oil mixtures. These can be made by simply adding about six percent fuel oil by weight to industrial or agricultural grade ammonium nitrate. It may also be purchased in prilled, pre-mixed forms.

A more powerful mixture is **"Crushed ANFO"**, in which some of the prills have been crushed prior to mixing. This provides better explosive characteristics and a higher loading density. Two other ANFO products are **"Aluminized Crushed ANFO"** and **"Aluminized High Density ANFO"** These products provide more blasting energy than non-aluminized ANFO mixtures.

Pre-mixed ANFO smells strongly of fuel oil and this oil has a tendency to evaporate and/or concentrate toward the bottom of the bag during storage, thereby rendering the product less efficient.

The various ANFO mixtures are generally suitable only for heavy loadings in large diameter shotholes, because their explosive reactions become more efficient as the column diameter increases and the quantity of the ANFO is increased. Blasting agents are seldom used in shotholes less than 4 inches in diameter, and are not reliable or efficient in small shots.

The are other cap-insensitive products used in blasting which are commonly called **"Blasting Agents"**, but which are not, since they contain certain high explosive ingredients. Keep in mind that a true blasting agent does not contain any explosive ingredient.

These **"Cap-Insensitive Explosives"** cannot be detonated by a standard commercial blasting cap, and have many of the good features of blasting agents including safety and economy. They often have greater strength and velocity.

The blasting agents and other cap-insensitive commercial explosives we are discussing are not fired by regular commercial blasting caps. Their firing must include a special high velocity primer or booster. This is necessary to provide the strong shock wave needed to initiate these highly insensitive nitroglycerin and non-nitroglycerin types.....are available for such purposes. Often, however, high velocity cartridged explosives such as 60% or higher grades of gelatin dynamites are used to prime cap-insensitive products, and provide good results at a much lower cost.

The use of blasting agents and cap-insensitive explosive products is generally confined to large blasting operations and industries which have their own well-established loading and firing procedures which best meet their own individual requirements. Such industries provide their blasters and trainees with explicit guidelines to follow. Accordingly, a further study of these products would serve no useful purpose.

Indeed, the reader is cautioned that the insensitive nature of these products can cause firing and column-propagation problems except under certain ideal and carefully controlled conditions. Their selection and use should be planned by an expert in that field.....preferably by a consultant of the manufacturer.

Author's Note:-

The bombing of the World Trade Center, in New York City, NY, Oklahoma City, five or so years ago was accomplished with 50-gallon drums of a cap-insensitive blasting agent in the back of a van and Ryder's truck. We witnessed the destructive power of those blasting agents via our television sets.

Notes:-

Black Powder

Black Powder is used only in a few specialized blasting operations today, and our discussion of it will be brief.

Black powder burns in the open at speeds from one to ten centimeters per second, and at pressures up to 30,000 pounds per square inch. It doesn't really have a **"Detonating Velocity"** because it doesn't detonate! Its rate of burning depends primarily upon the size of the grains. However, when closely confined the speed of the explosion of black powder varies from about 400 FPS, for the course granulation’s to a high of about 2,000F.P.S., for the fine.

These extremely low velocities cause only minimal shattering or fracturing of a target and this makes the product suitable for blasting where a minimum of shattering is desired, such as in quarrying solid architectural and dimension stone, mining granite for monuments and mining slate and flagstone.

An extremely hot, long-lasting flame is produced by the explosion of black powder.....along with heavy smoke and gases.....and because of these characteristics it should never be used in gassy mines.

Black powder ignites instantly at about 572 degrees f and any flame, spark, hot wire or other source of this degree of heat will readily ignite it. Commercially, it is ignited by safety fuse, electric squibs or igniters or by blasting caps or detonating cord. But it is heat.....rather than a primary initiating detonation.....which triggers ignition.

Black blasting powders are made in two forms. Black blasting powder and black pellet powder. As the names imply, the black blasting powder is a grained material available in different sized grains, and the pellet powder is pressed into cylindrical pellets about two inches long and 1 1/2 to 2 inches in diameter. The pellets have a 3/8-inch diameter hole through their center, through which a fuse may be laced.

Black powder is also available in two types or grades. A premium grade in which the potassium nitrate and a lower grade in which the potassium nitrate has been replaced with sodium nitrate. The former is much faster in action, somewhat stronger, and slightly less prone to absorb moisture. It is used in the quarrying of dimensional stone, granite and slate and also, for fireworks, safety fuse and certain boosters and igniters. The sodium nitrate type is used principally in coal stripping operations and in clay and shale mining.

There is a tendency to regard black powder products as less dangerous than commercial high explosives, because it is a **"Low Explosive"**. **This is a serious mistake! Black powder must be handled and used with great care because of its extreme sensitivity. It is more prone to accidental firing than commercial high explosives.**

NOTES:-

Black Powder Primer Cartridges

Since the priming of black powder was not discussed earlier, we will discuss it now.

The end-spit of flame from a safety fuse is all which is required to initiate black powder. However, we add to the certainty by making a primer cartridge. Like the high explosive primer cartridge, the fuse should be attached in such a manner that it will not pull out during normal handling and loading operations.

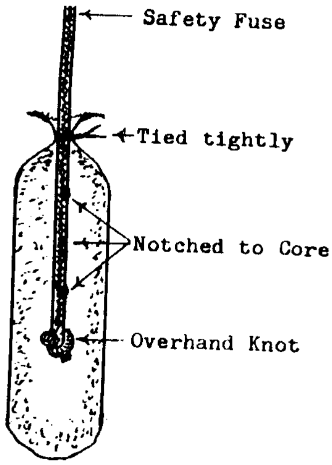


Fig. 73. "Black Powder Primer Cartridge", Granular.

With granular powder, tie an overhand knot at the end of the fuse and then notch the fuse down to the powder core every two inches or so for a distance of about 6". Take a paper tube or bag which will fit into the shot-hole. Fill this about half full with powder. Put the knotted fuse on top of this.....fill the tube to within two inches of the top.....and tie the top of the tube firmly to the fuse.

This primer is then positioned in the main charge of black powder.

As previously stated, black powder is also available in pellet form. Each pellet having a hole through the center through which safety fuse may be laced. Four such pellets are wrapped in a paper cartridge shell by the manufacturer. To make a primer cartridge for pellet powder, the end of the fuse is not knotted, but is cut off on a long sloping angle. The fuse is then notched down to the powder core every two inches for about six inches.

<u>Notes:-</u>

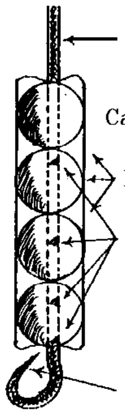


Fig. 74. "Black Powder Primer Cartridge, Pellets.

The fuse which has been cut on a long sloping angle and notched down to the core for about six inches, is then threaded through the center hole of each pellet in the cartridge. After it has been pushed through the cartridge, it is doubled back and forced up into the bottom hole.

The assembly is then pulled tight, and tested to insure that it will not likely come apart during loading.

To make black powder primers to be fired electronically, the primer paper cartridge should be made up as has been described. It should be half-filled with powder and then the electric cap or squib inserted. The tube or bag should then be filled to within two inches of the top and tied firmly around the leg-wires.

To make an electric primer cartridge employing black powder pellets, punch a hole in both ends of the cartridge containing the pellets. Then push the squib or cap all the way through. Pull it out the bottom a foot or so and then double it back and insert it in the top end. Then, pull the slack out of the leg-wires.

<u>Notes:-</u>

Permissibles

There is one area in which the blaster does not have a free hand in selecting his high explosives, blasting accessories and methods of firing. This is in certain mining operations, notably in gassy or dusty coal mines.

To reduce blasting accidents and dangers in mining, The US Bureau of Mines, regulates the explosives, equipment and techniques used in blasting in mines. These regulations are contained in the.

****

In, Canada, this is regulated by, **"The Explosives Branch of Mines and Energy Canada".**

Provincially, there are separate regulatory bodies in every province under the **"Worker's Compensation Boards".** i.e.:- **Occupational Health and Safety Division.**

Note:- Each State and Province has its own regulations governing the surface use of explosives, also, and these regulations should be studied and known by heart, by anyone involved in the explosives field. **That means the Site Superintendent; Field Engineers; Blasters; Blaster's Helpers/Apprentice Blasters; Union Representatives, etc., and anyone else involved with the blasting project, on-site**. **On top of this it is the responsibility of the Blasting Supervisor to make everyone aware of the regulations and to ensure that the regulations are enforced and safety maintained.**

In, Canada, there is a provision in the Criminal Code of Canada, concerning, **"Duty of Care"**. This section can in the event of an accident causing injury or death, result in the blaster in charge of the blast site, ending up facing 14-years to life in prison.

****

Explosives are designated **"Permissible",** and thereby are permitted to be used, when they have been thoroughly tested and approved by the Bureau of Mines or the Explosives Branch of Mines and Energy Canada, as safe for blasting in gassy or dusty mines.

All explosives produce a flame when they detonate and it is this flame which can cause gas or dust ignition. Permissible explosives are especially manufactured so as to give a small low temperature flash, of short duration. And obviously, an explosive must also have very good fume properties to qualify. No nitroglycerin dynamites are approved.

Permissible explosives are available in various strengths and densities and in velocities from a little over 5,000 FPS, to over 16,000 FPS

In addition to using only permissible explosives, the blaster in a mine must also use **"Permissible Accessories",** and follow **"Permissible Usage Regulations".** Some of the requirements are that shots must be fired by an electric cap of at least No. 6 strength. Explosives must be stored in surface magazines under approved approved conditions, and not be stored underground for more than 48 hours. Shots must be properly confined in a borehole by a non-combustible stemming material. Shots cannot be fired when dangerous amounts of gas are present. And the quantity of a shot must not exceed 1 1/2 pounds under some conditions, or three pounds under other conditions.

The regulations of the United States Bureau of mines and Canada's Explosives Branch, are extremely practical and necessary, and should be followed to the Letter! Their value is best demonstrated by the fact that there has not been a single proved instance of mine gas or dust explosion caused by a permissible explosive used in accordance with the regulations of the mine safety code!

Notes:-

Military Explosives

Many people seem to believe that military and commercial explosives are essentially the same products with different names and are packaged differently. **This is not so!** In selecting and developing explosives, military personnel and commercial blasters have entirely different requirements and properties. Consequently, military explosives are seldom used commercially, and commercial explosives are not used by the military.

Let's consider first what the military wants in an explosive. Since most of their explosives are used in bursting charges such as shells, bombs, grenades and so forth. or for military demolition purposes. They require explosives with very high velocities and great shattering power. Because of the exposure of military explosives in forward combat positions, they need products which cannot be exploded by small-arms fire.....and which are highly water resistant. Since military operations may be required in any climate they need explosives which retain their efficiency in any climate and when used over a wide range of temperatures. US military explosives must be able to endure prolonged storage at from minus 65 degrees F., to 160 degrees F., and remain operative!

Since military explosives must be carried by troops, they want high density and high power per unit of weight, plus packaging in shapes and sizes convenient for military operations.

Only highly specialized explosives can meet these rigid military requirements, and these are usually extremely expensive to manufacture. Cost, however, has never been a top military priority.

The commercial blaster has an extremely different set of requirements. He/She is very concerned with cost and economy. He/She often needs an explosive having lower velocities. He/She may need less dense explosives. He/She is often concerned with fumes, and most military explosives have extremely bad fume properties. He/She may require explosives which are safe to use in gassy mines. The commercial blaster wants explosives which are reasonably safe to handle and use. Yet, He/She is not concerned with whether or not they are bullet-impact safe. He/She needs products which will remain stable and efficient during normal periods of storage in his/her area, but not necessarily products which will endure prolonged storage at extreme temperatures anywhere in the world. He/She needs products which are easy to load into a shothole, not convenient to carry on his/her back.

Consequently, most military explosives are not of practical use to the commercial blaster, except under unusual circumstances. However, we will discuss briefly the more common military explosives.

TNT

Tri-nitro-toluene was first produced in 1902, and it is the most common world-wide military explosive. It is one of the least sensitive explosives and is bullet-safe. It is not effected by water, and will burn in small quantities without detonating. It is straw or yellow in color. It can be melted and poured into shells and other projectiles. TNT detonates at about 21,000 FPS It is also used as a sensitizer in water-gels and other commercial explosives.

****

TNT retains a memory of its original melting point temperature and if it reaches this temperature after having been originally cast, it can explode!

Extreme caution should be used if TNT is to be melted out of shells, bombs, grenades or mines that it has been used in, by demolition personnel.

****

Plastic Explosive, Composition C-3

This is a common US Plastic-type explosive which is putty-like, yellow, smelly and with a sensitivity comparable with TNT It has a high detonating velocity of 26,000 feet per second, and is ideal for cutting steel because of this velocity and its plastic form.

Plastic Explosive, Composition C-4

This is a dirty white colored plastic explosive which remains plastic over a wide range of temperatures but becomes brittle with extreme cold. It is odorless, waterproof and erodes less than other plastic explosives when left underwater for long periods. It has a higher detonating rate and shattering effect than TNT, at about 26,000 FPS

Composition B

This is a dirty white to yellow colored explosive made of a mixture of TNT, R.D.X., and wax. It is replacing TNT, to some extent in munitions and is used in shaped charges.

Amatol

Is a mixture of Ammonium Nitrate and TNT, with a relative effectiveness higher than TNT It is straw to white in color and is less sensitive than TNT It is made with varying percentages of ammonium nitrate, with the 80/20 mixture probably the most common.

PETN

Pentaerythritetranitrate is a white explosive sometimes used as a main charge, but more often as a secondary explosive. It is almost as powerful as nitroglycerin, with a detonating velocity of up to and over 27,000 feet per second. It is also used in detonating cord.

R.D.X.

This is sometimes called **"Cyclonite"**, and is a white explosive with velocities and shattering capabilities second only to nitroglycerin. It is used in mixed form as a military main charge explosive and also as the base charge in many types of blasting caps. It is also used in some detonating cord.

TETRYL

This is a yellow, fairly sensitive explosive, which is used as a military main charge and often as a secondary or "Booster" explosive.

Military Dynamite

Unlike commercial dynamites, this contains NO nitroglycerin. It is waterproof, buff in color and packaged in standard 1 1/4 X 8-inch cartridges. Military dynamites are relatively insensitive, with a maximum velocity of about 20,000 feet per second, and are used for construction purposes.

Ammonium Nitrate Cratering Charges

For cratering, ditching and quarrying, the military uses a commercial blasting agent in a 7-inch diameter, 24-inch long metal container which weighs 43 pounds. It is also called **"Nitromon".**

Other Less Common and Foreign Military Explosives Are:-

Explosive D

Ammonium Picrate extremely insensitive, and used in armor-piercing ammunition.

Nitro-Starch a highly sensitive gray explosive.

Picric Acid a bright yellow crystalline powder, rather sensitive, used in both secondary and main charges.

Pentolite:- a mixture of PETN and TNT, usually 50/50.

GunCotton:- or nitrocellulose made by treating cotton or sawdust with nitric and sulfuric acid.

Notes:-

Below, we show the methods of priming unpackaged plastic explosives with detonating cord and with caps. This is applicable to military explosives and to commercial products having plastic characteristics. It is important that the cap or cord be surrounded by certain amounts of explosive to ensure proper initiation.

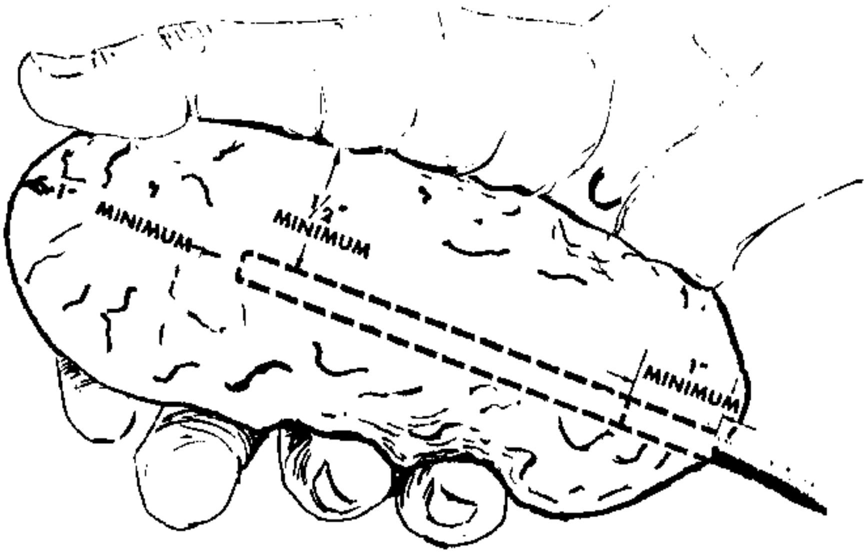


Fig. 75.   "Priming Unpackaged Plastic Explosives".

NOTES:-

Packaging of Explosives

When most people think of explosives, they think of the **"Standard"** dynamite cartridge which is a cylinder 1 1/4 inches in diameter and 8 inches long, wrapped in a waxed paper shell and delivered in 50-pound cases.

While it is true that this has been the most commonly encountered size and form of commercial explosives.....and will still serve most purposes.....explosives are available in many other sizes and forms.

Small-diameter dynamite cartridges are available in diameters from 7/8 of an inch to 2 inches and in lengths up to 24 inches.....large diameter cartridges are available in diameters up to 10 inches and in lengths from 8 to 36 inches. Four to six-inch diameters are the most common in the large diameter sizes.

The **"Shells"** or wrapping on such cartridges are most commonly manila paper which has been wax-treated before wrapping. In some cases, a spiral wound and glued paper shell with a moisture barrier is used, especially in the large-diameter sizes. Cartridges are also available with **Perforated Shells**, that is the wrapper is punched full of holes. The size, number and location of these holes is such that these perforated shells collapse readily when tamped, making it unnecessary to slit the shells before loading.

Dynamites can be purchased with the cartridge tapered at the end for easy loading, and also **"loose".....**packed in plastic or paper bags usually weighing 12 1/2 pounds, which can be "Poured" into a drillhole. And, dynamites may even be purchased in molded plastic cartridges, each fitted with a threaded coupler end for joining cartridges together to form a solid column of explosives.

Nitroglycerin is available in both liquid and solidified forms.

More recent developments include explosives in thin sheets like rubber matting, which can be molded, wrapped, cut and shaped. And, a liquid explosive comprised of two solutions which are not individually explosive but become a powerful high explosive when ready for use and mixed together.

Blasting agents are available ready-to-load in round metal containers from 3 to 11 inches in diameter.....in lengths from 12 to 24-inches.....and in weights to 85 pounds. They are also available in seamless steel cans fitted with couplers.....in spiral wound asphalt-lined paper shells with metal ends.....and free-running types which can be poured or blown into shotholes. In some high-use areas manufacturers will deliver free-flowing blasting agents to the site in a pump-truck and pump them into the borehole for you.

Black -powders for blasting are available in both granular and pelleted form. The former is solid in 25-pound metal kegs and 50-pound fiber cases containing two 25-pound bags. Pellets are pressed cylinders. Four pellets are wrapped in an eight-inch paper cartridge and these are packed in 25 and 50-pound cases.

Military explosives are found in plastic moldable forms, and poured or cast into blocks which are in turn encased in cardboard, plastic or metal containers. As previously mentioned most military explosives are in small unit, easily carried forms. Cartridge forms are less seldomly used.

Additional information on the sizes, weights, forms and other characteristics of commercial explosives may be obtained from your explosives dealer or manufacturer. Regardless of what type of blasting job you are planning or what conditions you will encounter there is likely a product which will very closely satisfy your needs.

Notes:-

Chapter VIII

Preparing Charges for Firing

Priming Charges

"Priming a Charge" is simply positioning a suitable primer or primer cartridge within a charge or column of explosives. The object, of course, being to provide the primary-initiating explosion needed to detonate the main charge efficiently.

When the primer is the first cartridge, or one of the first cartridges to be loaded into a borehole.....so it is situated near the bottom of the charge.....this is called **"Indirect Priming"**. The type of primer cartridge employed in such a loading will be one in which the base of the blasting cap is pointed toward the collar or opening of the borehole.

Regardless of where the primer is placed in a column of explosives, the base of the cap should ideally be pointed toward the main column of explosives. If you are placing a primer near the bottom of a shothole, and for some reason it is impossible or impractical to have the cap pointed upwards toward the main column, then load one or two cartridges into the hole before the primer cartridge. By doing this we at least have the base of the cap pointing toward the other explosives and not just toward the rock at the bottom of the hole.

"Indirect Priming" is generally considered a better practice than placing the primer near the collar. There are a number of reasons for this, the most important being that there is less chance of misfires caused by such things as the cap being separated from the primer.....the primer becoming separated from the main charge.....or the explosives becoming separated from each other during loading. Another advantage is that when loading problems are experienced, the entire charge may often be withdrawn by carefully pulling out the primer by the fuse or leg-wires.

Primer cartridges must always be situated toward the bottom of the shothole when engaged in multiple-shot delay sequence firing. Positioned there, it is much less likely to be cut-off or blown from the hole by an earlier-firing charge.

If you are firing single shots, or simultaneous multiple shots, you may position the primer cartridge toward the top of the collar of the hole. When you do so, that is, when the primer is the last cartridge loaded, this is known as **"Direct Priming"**. One advantage of direct priming may be to keep the primer from becoming immersed in water at the bottom of the hole. Another advantage is that you don't have fuse, detonating cord or leg-wires running down the full length of the hole, which you must then protect from damage during loading and tamping operations.

We recommend **"Direct Priming"** except in those cases such as just mentioned when **"Indirect Priming"** is clearly called for. We feel there is a greater degree of safety, since the primer cartridge.........is less subject to abrasion and pounding during loading and tamping. And, the less time we must work around a charge which has been primed, the better. However, don't use direct priming methods when firing a number of charges in a delay sequence.

In the drawing below, we illustrate a charge in which the primer cartridge has been positioned toward the collar of the borehole.....an example of **"Direct Priming"**, with cap and fuse.

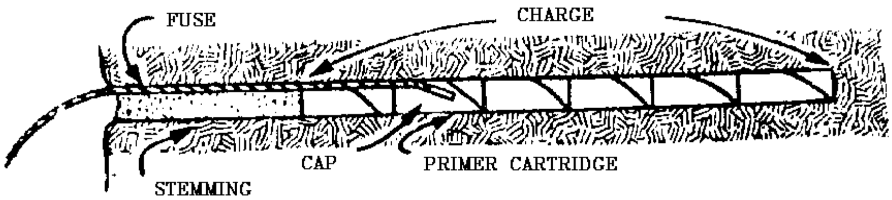


Fig. 76. "Direct Priming" with Cap and Fuse.

The illustration which follows shows a loading in which the primer has been situated toward the bottom or back of the shothole.....an example of **"Indirect Priming"** with a cap and fuse.

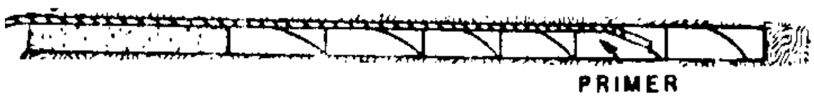


Fig. 77. "Indirect Priming" with Cap and Fuse.

When detonating cord is used for priming, the primer cartridge should be loaded into the hole first. The downline of the detonating cord runs the full length of the borehole. Since it will detonate all cap-sensitive explosives it contacts, the chances of a misfire caused by the separation of the cord from the primer.....or the separation of the explosives in the column.....is almost entirely eliminated.

Notes:-

Loading, Tamping and Stemming Charges

"Loading" is the process of placing an explosive charge, complete with primer, into a drilled, punched or dug hole.

"Tamping" is the compacting of the charge in the borehole so as to insure there are no breaks in the continuity of the column, and to increase the density of the charge and fill all available borehole space. And, "Stemming" is packing in inert material such as sand, clay or drill-cuttings, on top of the charge.

Generally speaking, the blaster, improves the performance and economy of explosives by packing and tamping them tightly so they completely fill all spaces in the shothole.....and by filling and tightly packing the remainder of the hole with a suitable stemming material. We will concern ourselves primarily with loading the shorter, small-diameter drillholes, since readers will most likely be involved in such operations.

First, an important word of caution! When a hole is drilled into rock heat is usually produced by the friction. The hole becomes hot. And, when you are re-loading explosives into a hole or cavity into which you have previously fired a charge, this may also be hot. **It is extremely dangerous to load explosives into a hot shothole!** Be sure the hole has cooled before you commence loading.

The basic tool in loading and tamping is the **"Loading Pole".....**often called a **"Tamping Pole".** For deep holes we use special pole sections which join together to make a very long wooden pole. But for most small blasting jobs a solid wooden pole 5 - 8 feet in length is sufficient. A straight-grained hardwood is the best material, and the best diameter for general use is 1 1/4 to 1 1/2 inches. The pole should be straight and smooth and the handle of a long-handled shovel.....with the rounded end of the handle cut off square.....makes an excellent loading pole for most small jobs.

Commercial loading poles are often offset at one end, as shown below. To prevent the pole from falling down into a vertical or angled hole.

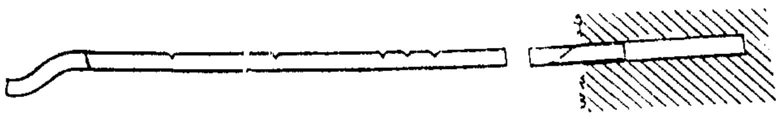


Fig. 78. "Commercial Loading Pole".

It's a good idea to mark or notch your loading pole so it can be used for measuring. If you do so, you can quickly measure the depth of a hole and quickly calculate the number of cartridges which can be loaded into it.

Under no circumstances should you use a loading pole with a metal or plastic tip. And of course never use a metal bar or pipe as a loading pole......**[June 1988 - Canadian Forces Base, Chilliwack, BC, Canada, there were 5-men and 1-woman killed while using an aluminum howitzer cleaning pole to tamp commercial explosives in the springing of a shothole. This was the wrong tool to be using.].....**and, you should not allow the end of a wooden pole to become frayed or pointed through use. If this happens, saw off the tip.

Before loading, first test the hole with the pole to confirm that it is the depth and diameter wanted, and to make sure there are no obstructions or rough spots which might interfere with loading. Such testing also serves to clean the hole to some extent.

In vertical or steeply-slanted holes any drill-cuttings or other residue will usually fall out or down. However, in horizontal holes this grit should be cleaned out.....otherwise, there is a probability it will be collected between cartridges as they are loaded, and separate them and thereby interrupt the column. This can cause a misfire! In large operations, drillholes are often cleaned out by means of water or compressed air hoses.

If it is not possible to clean out a horizontal hole well, then it is a good idea to place all the cartridges to be loaded together in the mouth of the hole.....in a solid column.....and push these all down into the hole in one operation. This reduces the chances of drill cuttings or grit separating cartridges, such as might happen if they were pushed into the hole one at a time.

As you know, cartridged explosives are covered with a paper **"Shell"** or **"Wrapper".** In the case of crumbly types, this wrapper or shell may be all that is holding it in shape. It is usually a good practice to slit the cartridge wrappers lengthwise before placing them into the hole. This is done by making two lengthwise cuts four to five inches in length with a very sharp knife. The purpose of this is to make the cartridges easier to collapse and compact when you later **"Tamp"** the charge.

However, there are circumstances under which the cartridge shell or wrapper should not be slit. Wrappers on cartridges containing explosives with little water resistance should not be slit if they are to be loaded into a wet hole, as the intact wrappers add water resistance. If you are loading into a hole with very rough or uneven walls you may wish to slit the wrappers as this could make loading even more difficult.

And, the wrapper or shell on a primer cartridge should never be slit, nor should the cartridge be tamped!

Black powder cartridges and the wrappers on permissible explosives, should never be slit or mutilated!

Primer cartridges should be lowered or pushed carefully into place, preferably with one cartridge between the primer and the loading pole to act as a cushion.

To load, we generally push one or two cartridges with slit wrappers into their final position with the loading pole, and then tamp or crush these. Sometimes, cartridges may be tamped sufficiently by merely pressing down firmly with the pole. More often, two or three light blows of the pole are needed to crush the cartridges. Different types of explosives offer varying degrees of resistance. You will get the "Feel" of when explosives have been sufficiently tamped. Continuing to tamp after explosives have filled-out to the walls of the hole is useless, and may be dangerous. **Never, tamp by pounding vigorously** Firm but gentle pressure and light blows are best!

When the first one or two cartridges have been tamped, two or more are added to the column. These are then pushed into position and tamped.....and so forth until all the cartridges have been loaded. Do not attempt to tamp more than two or three cartridges at a time. And don't tamp a cartridge until you are sure it has been pushed into its final position. If you crush it part way down the drillhole you may block the hole. Keep checking with your loading pole measurements so as to be reasonably certain that all cartridges have been pushed down into position before tamping.

Throughout the entire loading and tamping operation great care must be taken to guard against damaging or sharply kinking fuse or leg-wires leading to the primer cartridge. You must be especially careful when loading a rough or tight hole. Fuse or leg-wires should be kept taut, and held tightly toward one wall of the hole. The loading pole should be run down against the opposite wall.

When loading a shothole you must always leave space for adequate stemming. Explosives should never extend to less than eight inches from the collar of the hole. Preferably, more space should be left for stemming, and some states and provinces, specify the minimum length of stemming which may be used.

Always know approximately how many inches of stemming there are in any shothole. This is for your guidance and peace of mind should the hole misfire and it becomes necessary for you to dig out the stemming.

Stemming does more than merely add confinement to the charge. It also serves to protect the loaded explosives from accidental ignition or detonation. Accordingly, it should not be omitted, even if it is unnecessary from the standpoint of confinement!

Materials used for stemming should be non-flammable and should not contain any hard objects which might become dangerous projectiles or which may damage fuse or wires. **Commonly used materials listed in the order of their effectiveness are a mixture of 2 parts sand and 1 part plastic clay; clay; sand; loam; and water. In many drilling and blasting operations the finely-powdered drill cuttings are used for stemming.** If the borehole fills with water, stemming is not usually necessary.

From a practical viewpoint, moist dirt which contains no stones or rocks is reasonably effective for stemming. Often a blaster will carry a supply of water with which to wet down dirt at the site and thereby add to its packing characteristics.

In the stemming operation, a small quantity of stemming material should be carefully and gently pressed to a depth of two to four inches over the charge. Then, the remainder of the stemming should be progressively added and firmly tamped into the hole. Ideally, stemming in ground should be packed so that it is at least as solid as the surrounding earth.

NOTES:-

"Springing Shotholes"

It is occasionally desirable to concentrate more powder in the bottom of a shothole than could ordinarily be packed into it. An example of such a situation might be if we wish to lift a large rock out of the ground. In such a case we would not want to spread our charge throughout the length of the hole leading under the target, but would wish instead of concentrating it directly underneath where it could exert a lifting pressure directly under the point of greatest resistance.

It may be possible to dig this chamber or pocket for explosives by hand.....if it is not too deep.....using a spoon-type shovel or post-hole auger. In many instances this will prove most practical. However, in some cases we may be choose to enlarge the hole and form a chamber through the use of explosives. The procedure of enlarging a shothole with explosives preparatory to the main loading is called **"Springing"** or **"Chambering"** and the product is called a **"Sprung Hole"** or a **"Springer".**

Whether or not springing will be practical in a particular operation will depend upon a number of factors. most important of which is the nature of the material in which the pocket is to be formed. In clay and heavy soil, the springing charge creates the chamber by tightly compressing the surrounding material. In rock, the chamber is formed through fragmenting the material and blowing the fragments out of the drillhole. Springing may not work in loose material, because the pocket may collapse immediately after the shot.

Getting back to our problem of lifting a large rock from the ground.....if circumstances are favorable the easiest method of making a pocket under the rock for our main charge may be to drive a small-diameter hole with a bar and sledge and load and fire a very small springing charge in the bottom of that hole.

The size of the springing charge you use will vary with the material to be blasted and the size of the chamber you wish to produce. This must often be determined by experiment until experience is gained. Most springing charges you are likely to use in earth will be very small. Often, one-eighth of a cartridge is sufficient. Seldom would you likely exceed one-half to one cartridge.

Keep in mind that you don't want to spring a hole larger than is necessary to hold the quantity of main charge explosives you are planning to use. If you do, you'll be left with the job of refilling leftover air-spaces!

When working in rock, the blaster uses a rough guide the formula that each cartridge used will create a chamber large enough to hold 6 to 8 cartridges.

When placing springing charges, full stemming is not usually necessary or desirable. Just place enough un-packed stemming material over the springing charge to protect it from accidental ignition.

Keep in mind that a springing charge will create very high temperatures in the hole and ample time must be allowed for it to cool before loading!

When working with deeper holes sprung in rock at least two hours should be allowed for cooling. A much shorter time is necessary when a short hole is sprung in soft material with a small charge, especially if there is good air circulation. However, a minimum of 30 minutes is always required for cooling. Keep in mind that some materials in sprung hole will retain the heat longer than others. And, it is possible for the springer to have ignited materials such as wood, so keep alert to signs of smoke.

Notes:-

<u>**Chapter IX**</u>

A Typical Small Blasting Job

To better understand the information contained in this and previous chapters, let's consider a small blasting job.

For our purposes we'll assume we will be using cap and fuse, and will be blasting in an isolated area on our own property. We'll assume we have suitable explosives on hand.

1. Study the situation and the proposed blast area, considering all possible sources of danger or property damage. Locate a nearby area offering complete protection from the blast and flying fragments, and time how long it takes you to walk from the blast site to that area. Study the material to be blasted.....the surrounding soil conditions, possibility of fire hazards and the availability of good stemming material. Determine how to best secure the area to prevent some person from wandering into the blast site. **Careful surveying and planning is essential!**

2. Don't guess wildly on the quantity of explosives necessary or the size of the charges. Consult your loading tables. [Most explosives suppliers can give you loading tables for most projects.] Make some tests-shots if necessary, although this is seldom practical on a small job. Seek advice from your explosives dealer if necessary.

3. Beforehand, consult the appropriate material in this manual to refresh your memory on the particular type of job you are planning. And schedule the job for a time when you know you will not be rushed or interrupted.

4. After digging or drilling your shotholes, clean them thoroughly.

5. Bring the explosives and fuse to the site of the proposed shot. Then, make a separate trip for the blasting caps!

6. Make sure you have all the tools you will need at the site, including cap-crimpers in good condition, a sharp knife and wooden safety matches.

7. Remove all unnecessary persons from the area, and make sure anyone working with you knows exactly what their duties are, and safety precautions they are to observe.

8. Cut and lay out your fuse. Examine it for any defects. Cut it to a length so you will have at least 24-inches and preferably 30-inches extending from the collar of the hole after the primer has been inserted. Don't cut any fuse less than 72-inches in length, and trim at least 1-inch from each end of the fuse.

9. Make up your primer cartridges with great care and at a safe distance from your explosives supply, using only approved methods. Punch the cartridges with the handle of your crimpers or with a hardwood dynamite punch. Don't force the fuse into the cap, or the cap into the cartridge. Then, test each primer to ensure that the cap will not be pulled from it during loading operations.

10. With your <u>**wooden loading pole**</u> check that the shothole is the desired depth, is free from obstructions, and is ready for the charge.

11. Using your <u>**flat-ended wooden tamping pole**</u>, press the first cartridge of the charge to the bottom of the hole. If you are indirect priming, gently press the primer in next, using another cartridge as a cushion between the primer and the loading pole. Press the balance of the charge home, preferably one cartridge at a time, being cautious not to damage the fuse.

12. If cartridges are to be tamped to ensure maximum loading density, the wrappers should be slit...but not cut almost completely off or removed...before loading. Then each cartridge is compressed with the tamping pole after it is pressed home. Tamp with firm pressure on the pole. Don't pound charges or use unnecessary force. Don't tamp until you're sure the cartridge has been pushed completely home. And, under no circumstances should the primer cartridge be slit or tamped!

13. Using fine sand, clay, or earth...but never rough gritty material or material containing hard objects...loosely tamp about two handfuls of stemming material against the charge. Continue adding stemming and tamping a little firmer until the last 8-12 inches has been added, and until the shothole is filled to a point about 12-inches from the collar. If blasting in soil, the stemming should ideally be packed as firmly as the surrounding soil. Wetting the material down will often help in this respect.

14. The shot is now ready for firing, but before doing so the shooter must be assured that everyone is clear of the danger area and that every approach is guarded. Warning horns, whistles, or other signals which are thoroughly understood by everyone in the area should be used to signal the intention to fire. They must also check to ensure that all explosives, and all tools and equipment, have been removed a safe distance from the blast site. Finally, they should shout **"FIRE"**, and ignite the fuse in the proper manner.

15. The blaster should watch carefully for the ignition spit from the fuse signaling that it has been lighted. Then walk to their previously selected place of safety. They should time the shot, and keep everyone under cover until it has fired. After the shot, keep out of the area until the smoke and fumes have cleared.

16. If the shot fails to fire, wait under cover for at least one hour. If smoke is coming from the hole, wait at least one hour after the last smoke is seen. Then, use recommended procedures for handling the misfire.

Obviously, these directions will not apply in every detail to every blasting situation, nor would they be complete in every instance. However, they should refresh the reader's memory and provide a rough step-by-step guide to firing a simple shot.

Notes:-

TOOLS

We could describe the operation of all the various rock drilling equipment. Some of this equipment is capable of making hundred for holes in hard rock. Some will make holes over nine inches in diameter. Her equipment can drill numerous hole at the same time, on a pattern. Some machines have been designed especially for a particular type of operation, and much of it is sophisticated. The operation of such equipment would fall within the realm of heavy equipment, and is beyond the scope of this manual.

However, we will describe some of the basic tools such as are used in smaller property improvement type blasting projects where there is not extensive drilling in hard rock. Tools which anyone can readily obtain, and which will be adequate for a wide variety of work such as open-top ditching, rock and stump removal, making ponds and water-holes, subsoil and other agricultural blasting, and many other projects in which drilling hard rock is not involved.

It is not suggested that you will need all of the tools described, nor that you might require tools we have not described.

First, you'll need a pocket knife...for such jobs as slitting or cutting fuse, slitting cartridge wrappers, etc.

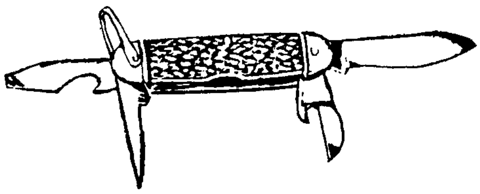


Fig. 79 Pocket Knife

NOTES:-

Driving Iron and Sledge

The sledge and bar are used for driving shotholes in earth and other soft materials. The most common iron is 4 - 5 feet in length, made of 1 1/2 inch octagonal steel which has been drawn to a six-inch point at one end. An eight pound sledge is most often used.

It is easier to drive and remove the iron if it is hit on the side from time to time.

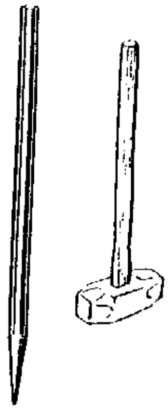


Fig. 80. "Driving Iron and Sledge".

NOTES:-

Bulge-point Driving Iron

This iron is shaped so it can be pulled out more easily than a straight iron, because there is less suction, making it especially useful in wet and sticky clay soils.

It is a six-sided steel bar, 1 1/2 inches in diameter, one end of which is first drawn out to a larger diameter of about 2 inches and then pointed.

It may be loosened with a wrench.

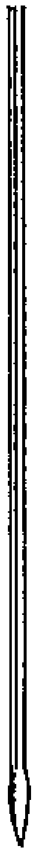


Fig. 81. "Bulge-Point Driving Iron"

Earth Auger

An Earth Auger is good in hard or clay soils. The length of the bit should be 12 - 18 inches, and the diameter 2 inches.

The bit is attached to a standard one inch pipe, and the handle made with a **"Tee".** Using extensions, one can make holes to about 18 feet.

Other types of post-hole augers and diggers may also be used.

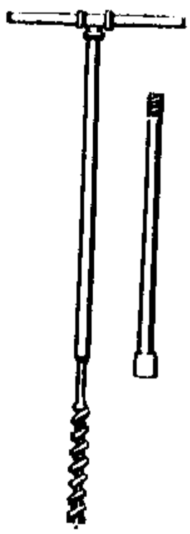


Fig. 82. "Earth Auger".

<u>NOTES:-</u>

Long Handled Shovel

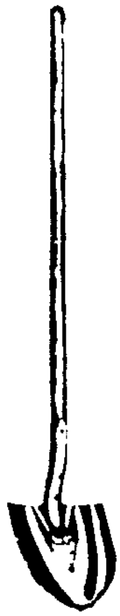


Fig. 83. "Long Handled Shovel".

NOTES:-

Spoon

A spoon-type shovel with a scoop from 1 1/2 to 4-inches across is used for making and cleaning holes.

Sometimes, instead of a handle on the opposite end of the spoon, this is made into a chisel point for cutting roots.

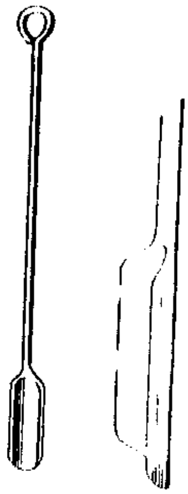


Fig. 84. "Spoon".

NOTES:-

Miner’s Spoon

This variation of the previously described tool is a metal rod with ends forged into small pans at right angles to the rod. The pans are 1 5/16 inches in diameter. This tool is used for lifting material from small diameter holes such as those made by a rock drill.

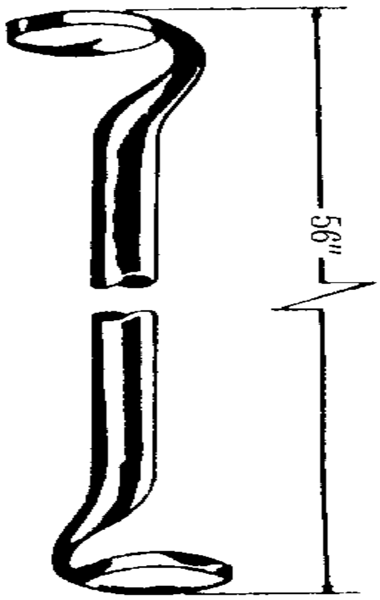


Fig. 85. “Miner’s Spoon”.

NOTES:-

Wooden Auger

This tool is extremely useful if you are removing tap-rooted stumps or blasting trees or timbers.

The overall length should be about six feet, with the auger about 18-inches long and 1 1/2 inches in diameter. A hollow-center auger should be used, which differs from regular augers in that the flute is hollow so that shavings may pass up through the center.

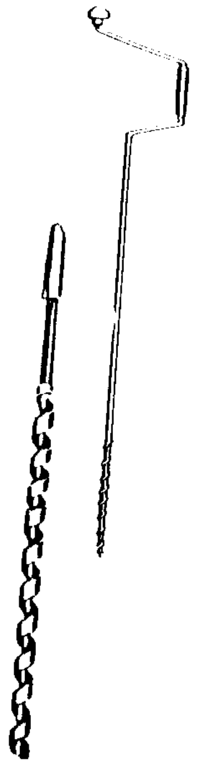


Fig. 86. "Wood Auger".

Unlike the brace and bit, the knob on this auger doesn't line up with the bit, but extends further in the opposite direction from the crank handle. So, you don't use it like a brace, but move both hands in a circular motion.

Tee-handled augers are also made, with and without ratchets.

NOTES:-

Masonry or “Star” Drill

This tool is used for hand-drilling holes in stone and concrete. The cutting edge is placed where the hole is to be drilled, and the head is struck with a heavy hammer.

The drill must be rotated slightly after each blow to clear the chips from the hole and keep the drill from binding.

Drilling with this tool can be a slow and hard job, and the user should always wear safety goggles!

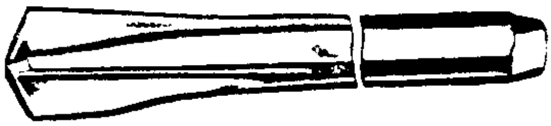


Fig. 87. “Masonry or `Star’ Drill”.

Air-powered “Blockholing Drills” may be either purchased or rented if considerable drilling is to be done. A large air compressor is required at the site. These drills may be hand-held or jack-leg mounted, and are suitable for drilling small diameter shotholes up to about 30-feet deep.

A tool which is especially handy in property improvement type blasting is a small-diameter metal rod which can be used as a probe to test ground conditions...determine how deep boulders are, locate underground roots, and other such exploratory probing. This can be made from a “springy” quarter-inch steel rod, six to eight feet long, by simply sharpening one end.

Readers with tractors can obtain earth augers and drills which can be operated from power take-off. And, holes can be often be punched in softer materials by using a punch bar attached to the hydraulic unit of the tractor.

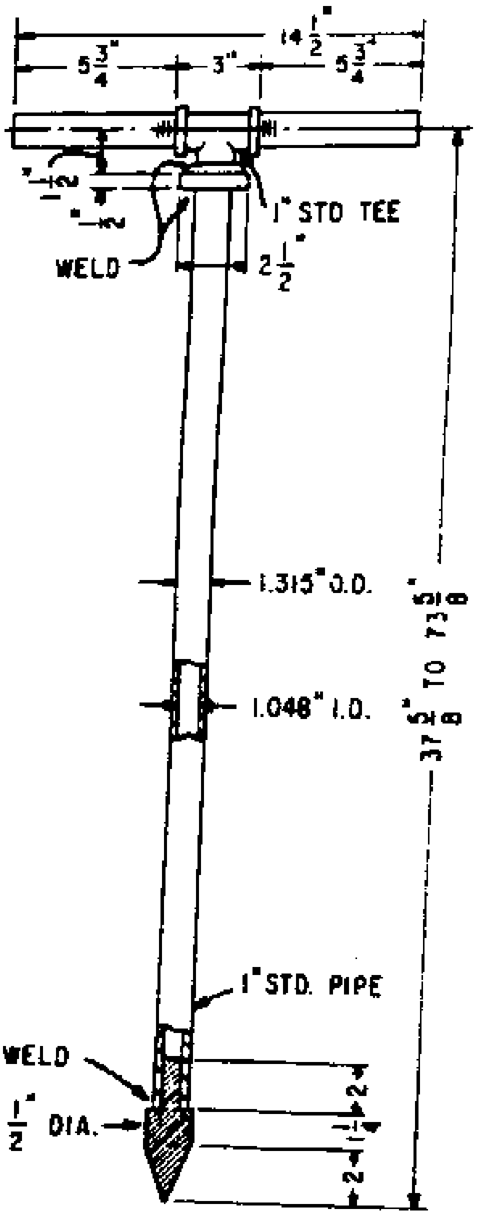
An extremely practical tool is the **“Ashley Core Punch Bar”.** It is especially useful in ditch and pond blasting, and all types of blasting in soft materials. It is comprised of two sections, a core section and a shell section. In soft mucky soils, the core alone is used to make shotholes simply by pushing it in with the weight of the body.

In harder soils, both sections are used. The core is lifted and hammered downwards inside the shell, like a pile-driver, driving the shell down with surprising ease.

<u>Note:-</u>

This would be a very good portable tool for military purposes, such as springing shotholes to enable personnel to blow up roads to impede an enemies travel.

When working in sand, gravel and other loose materials, a regular punch bar is unsatisfactory, because the hole it produces fills up as soon as it is removed. With the **T-Core punch bar**, both sections are used. The hole is punched or driven in, and then the core is removed. This leaves the hollow outer section still in the ground, which may be loaded with primed charge. The outer shell is then removed. The material will then most often collapse around the charge, making stemming unnecessary.



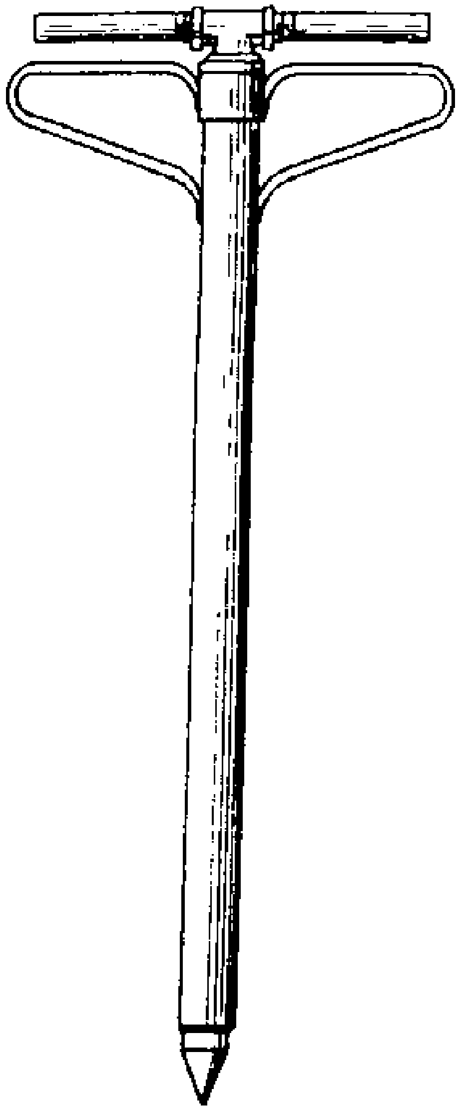


Fig. 88[a]. "Plans for making an Ashley Core Punch Bar".

Fig. 88[b]. "Plans for making an Ashley Core Punch Bar".

NOTES:-

CHAPTER X

Preventing Misfires and Accidents

It is rarely that premature, delayed shots, misfires or blasting accidents are caused by faulty explosives, caps, fuse or blasting accessories. And, when this does prove to be the case, it is almost always found that their failure was the result of carelessness in storage or handling. Not because defects during manufacture.

Human error or carelessness is unquestionably the cause of ALMOST ALL misfires, premature and delayed shots, and other blasting accidents. Misfires must be regarded as serious accidents, whether or not anyone is hurt, because they add unnecessarily to the hazards of blasting.

The keys to avoiding blasting accidents are:-

1. To thoroughly understand all the recommended practices and Do's and Don'ts for transporting, storing, handling and using explosives, as spelled out in this manual.

2. Follow these recommendations to the letter. And always remain alert and paying close attention to everything you do when working with explosives.

3. Maintain an attitude of safety consciousness. Always giving top priority to safety considerations.

4. Never gambling by using explosive products, caps, fuse, firing-wires or other products or equipment which you suspect may be damaged or deteriorated. It only takes one faulty link in your firing train to produce a misfire!

5. Knowing and following proven blasting practices, especially in making up primer cartridges, priming shotholes, laying out blasting circuits, and selecting and using blasting accessories. Follow the lead of those with long years of experience.

Don't experiment or improvise!

You just can't learn blasting techniques safely by trial and error.

6. Never hesitating to contact your explosives dealer or manufacturer for expert advice or assistance when you are faced with an explosives or blasting problem. **"When in doubt about a task, why should you be scared to ask"?**

7. On the other hand hesitating to put much faith in information volunteered by others. In every area there seems to be that ex-army type who wants to tell you what to do, or the old timer who is an **"Expert".** It always pays to listen, but don't follow their advice until you check it out thoroughly through more reliable sources.

8. Carefully organizing your blasting operations so you know exactly what has to be done and the sequence in which it is to be done. Allow ample time for every task to be completed in an orderly manner, so there will be no necessity for rushing and carelessness.

9. **TEST!** Test your cap before making up primers. Test your fuse or blasting machine. Test firing wires. Test your galvanometer. Test your complete firing circuits. Test your primer cartridge to be sure they will hold together during loading. Test everything you can before firing, in order to identify faulty products, equipment or techniques before these can cause you problems.

10. **When you are hiring or supervising people on a blasting project:-**

    [A] Keep crews to the minimum number needed;

    [B] Select only mature men or women who have good sense, and who are careful by nature, and who are reasonably intelligent. Preferably persons with explosives experience;

    [C] Assign each person definite tasks and make sure each knows exactly what their jobs and responsibilities are. The safety precautions to be observed. Signals for firing, etc. Make it clear that nobody is to perform any job or operation unless they have been specifically assigned to do so;

    [D] Don't allow persons with little or no experience to work on their own until they are thoroughly trained, and then continue to supervise all persons working on or near the project to insure that safe handling practices are being followed and that no short-cuts are being taken;

    [E] Don't permit gossiping, kidding, horse-play or other activities among the crew which may take their attention away from what they are doing. Making it clear that they must devote 100% of their attention to their jobs in the interest of mutual safety;

    [F] **<u>Immediately terminate and report any individual who is a show-off, is careless, or who violates safe-handling practices willfully!</u>**

11. Observe special precautions before firing, including keeping personal control of the firing device. Having a positive warning signal known to all persons in the area providing adequate cover for personnel materials and equipment. Guarding access to the blast-site to prevent the approach of any unauthorized person when preparing to fire. And NOT FIRE the SHOT, until you know it is safe to do so.

12. After firing, forbid the approach of any person to the blast area, until the smoke and fumes have cleared, and you know there are no delayed shots, misfires, or burning holes.

13. If and when a premature shot, delayed shot or other form of misfire occurs, follow the prescribed safe handling procedures which are described in this manual. And, regard this as evidence of carelessness or bad practices, and investigate why it happened and who was responsible. Then, take the steps necessary to prevent a recurrence.

Let's now consider some of the more common causes of premature and delayed shots, and other misfires.

Premature shots are especially dangerous because they occur unexpectedly...Sometimes, when personnel are still working around the hole. Fortunately, they don't happen very often, and the blaster who knows what they are doing and works with care should never be exposed to the danger of a premature shot.

One of the most common causes of premature shots is a side-primed primer cartridge in which the blasting cap has been pushed almost completely through the side of the cartridge. When such a primer is loaded, the sensitive cap may be forced completely through the cartridge and be detonated by friction against the side of the borehole or blow during loading and tamping.

Premature shots may also occur during loading when the cap is pulled from a poorly-made primer cartridge and exposed to abrasion or blows.

Another cause of premature shots during loading is rough handling and too severe tamping of the primer cartridge. This danger is increased greatly if the wrapper on the primer has been slit. **Primers should never be slit nor tamped!**

Deteriorated explosives can become extremely sensitive, and have caused premature explosions during loading.

Premature shots may also occur when firing with electric caps, through lightning strikes or other sources of electrical energy entering the blasting circuit. Lightning strikes are probably the only source of premature shots which the blaster cannot eliminate completely.

When working with cap and fuse, premature shots have occurred while igniting the fuse, when sparks of flying match-heads have fallen into unstemmed holes and set the explosives afire. This is avoided by proper stemming and having sufficient fuse lengths to permit lighting the fuse a short distance from the collar of the shothole.

There have been cases where the person lighting fuse didn't realize it had ignited because of improperly preparing the fuse or an improper method of lighting which masked the ignition-spit. Make sure that fuse-ends have been freshly and properly cut, and use a lighting method which permits you to see and recognize the ignition-spit.

Premature shots have also occurred because of the use of damaged safety fuse, and/or the practice of folding and stuffing excess fuse down into the borehole to get it out of the way. These practices can cause the flame from one part of the fuse to light another section of the fuse much closer to the primer. Safety fuse should never be positioned so that one part of the fuse is laying near or touching another section, such as when coiled or folded. And, flame from a ruptured section of fuse can directly ignite explosives, especially when the charge has been indirectly primed.

When a charge does not detonate when expected, but may explode sometime later, this is called a **"Delayed Shot"** or a **"Hangfire"**. While not as hazardous as a premature shot, this is nevertheless a dangerous occurrence. It is also costly, since blasting and other nearby operations must be suspended.

One common cause of delayed shots is the too-loose crimping of blasting caps onto safety fuse. If the fuse becomes separated from the cap during loading, the end-spit of flame from the fuse may ignite the explosives, and these may burn until the heat causes an explosion, or detonates the blasting cap. This is often called a **"Burning Hole"**. **A burning hole should never be approached.**

Delayed shots have also been caused through the use of too weak a detonator with an insensitive explosive, and by defective detonators. These don't have sufficient strength to detonate the charge, but merely set it afire. Heat and gas may eventually explode the charge. It is extremely important to follow the manufacture's recommendations as to the type and strength of cap or detonator or primer to be used with their less sensitive explosives and blasting agents.

I would like to emphasize that working with explosives is not all that dangerous if a blaster knows their stuff.

Blasters are more likely to be killed by a drunk driver while on the way home from work, than they are by the materials they work with.

Accident Reports

Let's now, consider some other accidents which occurred involving explosives, in the hope that we can learn from the unfortunate experiences of others. Keep in mind that many accidents involving explosives leave no witnesses or evidence to tell exactly what happened.

Two men in a mine were carrying dynamite and caps on the same cart. It is assumed that the caps detonated the explosives, and both men were killed.

A workman was carrying a carton which contained both dynamite and blasting caps. He stumbled and dropped the carton, which exploded and killed him and injured two companions.

Explosives and caps should never be stored or conveyed together!

A blaster carried a sack of blasting caps with him to a shelter while awaiting a blast. While jumping back to avoid being hit by a flying rock, he stepped on the sack containing the caps. They exploded, and he died from his injuries.

Leave caps in their containers, until they are actually to be used!

A miner tried to force a length of fuse into a blasting cap and twisted it violently. It exploded and injured him.

Men of a work party were smoking in a shack in which there was an open carton of explosives. Some fuse primers were also in the carton. A fuse was accidentally ignited, and though all the men tried to escape, three were injured and the building was demolished.

A blaster laid a partially filled box of detonators on the ground near the open door of a blacksmith's shop at the site, while he made up fuse primers. The caps were exploded, apparently from a spark from the forge, and three men were injured.

A man was seen priming a dynamite cartridge with a fuse about 12-inches long, intending to light it and throw it onto ice. It apparently didn't light, so he cut off a little more of the fuse and lit it again. The cartridge exploded in his hand. He was terribly maimed and died in a few hours.

A man laid a charge with a fuse less than three feet long to blow a hole for a utility pole. He lit the fuse, but no explosion followed. He returned to the hole and made two or three attempts to light the fuse, cutting off pieces each time. After he succeeded in lighting the fuse it was so short, he didn't have time to get sufficiently clear, and he was seriously injured by the blast.

Three blasters on road work set off seven charges with two-foot fuses. One of the men evidently had trouble lighting his fuse and was delayed so that he failed to get clear of the blasts. He lost a leg and suffered from other injuries.

A quarryman caused an explosion which seriously injured him when he tamped a dynamite charge with an iron rod.

Two men were killed and one injured by the explosion of a charge when it was being rammed home. The explosion was probably due to the breaking of the cartridge in the presence of grit, the loose dynamite being exploded by fiction.

Clean shotholes! Don't force when loading or tamping!

A farmer blasting rock thought he had allowed sufficient time for a charge to detonate, and thought it had failed. He went to examine it, and the charge exploded and blinded him.

Another farmer was trying to blast a rock ledge in his orchard. He lit the fuse, but wondered if he had properly lit it. He returned to the shothole to relight the charge it exploded, killing him and injuring his sister who was nearby.

A man working in a lumber-camp lit the fuses of three shots, on hearing two explosions, he returned to investigate the third charge which then exploded, killing him.

A well digger set a charge and when the blast did not occur as soon as he expected, he returned to investigate the cause. The charge then exploded, severely injuring him.

A logger blowing stumps took cover behind a tree close to the blast site. He was killed by a piece of the stump which rebounded from a tree behind him.

A truck driver took cover by standing behind the raised box of his dump-truck. A piece of rock from a blast was thrown 300 feet, struck the cab of the truck, rebounded and struck the head of the driver, killing him.

A man was killed when he was operating a power drill on a construction project. He apparently drilled into a charge of explosives which had previously been loaded into the face, but had failed to fire.

A seven-year-old girl wandered about a construction area and nobody stopped her. She was killed by a dynamite blast, because no guards were posted.

Each of these accidents, in which real people were severely injured or killed, happened because simple and sensible explosives handling and blasting practices were not followed.

Explosives are dangerous only to the ignorant or careless.

Let’s learn from their unhappy experiences!

These accident reports courtesy of the Explosives Branch, Ottawa, Ont., Canada

Let us now consider some cases in which persons were found to be negligent and had to pay damages as a result of blasting accidents.

Again, it is our hope that the reader will learn from these actual case files.

Explosives were being used by a blaster to remove stumps. Continuous noise from the operation caused egg production loss at a nearby chicken farm. It was proved that the noise level prevented the chickens from laying, and the farmer obtained a judgment against the blaster.

A young boy was sold lead azide by a chemical house. He handled it improperly, and lost a hand. The chemical house was found negligent and liable.

Carrying explosives together with electric blasting caps in a pick-up truck, two blasters parked outside a motel. During the night a severe lightning storm developed. Lightning struck, firing the unshunted blasting caps. The resulting explosion demolished cars and part of the motel, killing two persons and injuring several others. The blasters and their employer were held liable for carrying explosives and detonators simultaneously, and for parking the improperly packed truck in a populated area.

Two quarry operators were waiting for smoke to clear after detonating several charges. One man, believing all charges had fired, went to investigate without signaling the Master Blaster. Two charges, delayed by wet fuses, detonated and killed him instantly. The quarry firm was held liable for not providing protection areas and not properly instructing the new man.

A man loaded several cases of dynamite into his truck. When a box dropped, it blew up the truck and he was killed. Causation for the man's death was the box's lowered impact force due to aging of the nitroglycerin. Liability for the man's death was the firm's for failing to provide proper loading facilities and for allowing aged explosives to be handled.

During the building of a bridge, a contractor was blasting for foundation support, and broke a water main about 100 feet away. Testing proved that the earth-shift due to blasting caused the main to break, and the contractor was held liable.

An explosives expert was removing a large generator shaft in an electric power plant, using mild 1/2 pound charges to slowly free the shaft. After nine shots, the shaft was released, but the 9-inch shaft then fell from the generator and rolled down a hill, destroying a truck and killing the driver. In addition, the 7-ton shaft sustained $30,000.00 in damage. It was proved the expert was at fault for not providing for securing the shaft when it was released, and he was found liable for the damages.

Again, it is hoped that the reader will recognize that each of these accidents happened because someone failed to follow prescribed rules for storing, handling, transporting or using explosives. **It is hoped that these real cases will impress upon the reader, the price which is paid on occasion, when these rules and good common sense are violated.**

There is one rule which takes precedence over all others. It is;

Don't allow any set of rules or instructions take the place of thoughtful caution and good old common sense when working with explosives.

Notes:-

Handling Misfires

Fortunately, the blaster who knows what he is doing and follows prescribed methods of storing, transporting, handling and using explosives will seldom experience a misfire.

However, as might be expected, misfires are more common in large blasting operations involving large numbers of charges, elaborate blasting circuits and delayed-firing series. In any event, misfires must be recognized as a possibility, and a blaster must know what to do when a misfire happens.

First, let's make one thing very clear. **Working near a misfired charge is unquestionably the most dangerous operation associated with blasting! <u>The recommendations in this manual will if followed, reduce the hazards to a minimum</u>. But, there is always an element of danger and uncertainty in coping with a misfired charge.**

Because of the wide variety of blasting operations, local laws, company or industry regulations, circumstances, and so forth, it is impossible to present a hard and fast set of rules to follow. Obviously you must abide by any Federal, Provincial and Local Laws or Regulations, and those within your company. Frankly, we don't agree with some such laws and regulations. We can only make broad recommendations which will be suitable in most cases.

When you have just fired a shot and are waiting for the smoke to clear before entering the blast site, examine the area from a distance to determine if all charges have fired. Be particularly alert to any sign of smoke coming from a shothole. Don't walk back into a blast area as the smoke clears without examining it for evidence of misfires or other dangers!

If you discover evidence of a misfire, you should assume initially that it is a <u>"Delayed Shot</u>", which is likely to detonate at any second. <u>With this in mind you would not approach a misfired charge for a period of at least one hour!</u>

If smoke can be seen coming from the borehole, it is a <u>"Burning Hole"</u>, <u>and should not be approached for at least one hour after the time the last smoke is seen!</u>

After an hour has passed, it may then be assumed that the shot is a misfire rather than a delayed shot or hangfire, providing there is no evidence of the hole burning.

If electric methods of firing are being used, the blasting machine or source of electric current should be disconnected immediately.

Preferably, only one person should approach and work on a misfired hole.

Generally, the most practical and safest way to handle a misfire is to attempt to fire the shot again.

If the charge was electrically primed and the cap leg-wires are accessible, these can be tested with the blasting galvanometer. If the circuit tests complete, the leg-wires can be hooked up to the leading wire, connections checked, and the charge fired again. If the original failure was due to insufficient electric current or poor connections, it may then fire. Frequently misfires are experienced simply because the charge was not hooked into the firing circuit in the first instance.

If the charge still fails to fire, or if the cap and fuse method of firing were used, then the charge must be re-primed before it can be re-fired. This calls for digging out all or most of the stemming material from the top of the charge. This is done with the hands, or a small piece of wood. Never use metal tools for this task, and work cautiously. Use the fuse or leg-wires as a guide to follow the borehole down to the charge.

Once the top of the charge has been exposed, you may then re-prime the charge with a carefully made, top-primed cartridge placed on the top of the main charge. **<u>The original primer is not removed or</u>**

disturbed. You merely re-prime the charge with another primer, and then fire the new primer cartridge. The entire charge is almost certain to fire.

In making a primer cartridge to re-fire a misfire, it is a good idea to use a high velocity explosive. And, you would naturally follow all the normal precautions which you would observe before firing any other shot.

In digging out large quantities of stemming such as might be the case with deep shotholes, it is a good idea to wet the stemming with water from time to time. This makes it easier to dig, adds to the safety of the operation, and adds to the certainty of propagating the main charge should a little stemming remain between the misfired charge and the new primer.

In large blasting operations the stemming may be washed out with water hoses, or blown out with compressed air. But care must be taken not to disrupt the column of explosives. And, you'd not expose explosives with little or no water resistance to much moisture. Where granular uncartridged explosives are involved, the entire charge is sometimes washed from the hole with a water jet.

Unless your Federal or Province, or local laws forbid the practice, we recommend that misfires be re-primed and fired again, in the manner just described.

We do not recommend procedures such as drilling another hole alongside the misfired hole and firing another charge in the second hole, attempting to expose the unexploded charge by "Benching" or shooting other nearby shots, unless you are compelled to do so by laws or other regulations which govern your operation.

Sometimes explosives from a misfired hole will have been blown or drawn from the hole by a nearby charge which fired. If this happens, great care must be taken to locate and gather up all such explosives. Otherwise they might be struck by equipment at some time, and explode accidentally. Or, such explosives may be found by children or other persons, and cause a serious accident. Keep in mind that such explosives may have become sensitized by the shocks or partial detonation.

The most dangerous practice that we've seen in handling misfires is attempting to dig the charge from the hole with picks, shovels and crowbars!

Never be persuaded to follow such an unnecessary and dangerous practice!

On the matter of waiting a full hour [most federal, provincial laws stated a minimum of one-half hour] before approaching a misfired hole, it may be that you will be pressured to reduce this time, especially if you are working on a larger project and this will cause an overall delay in the work. The delay of one hour can be extremely costly, especially if personnel and equipment at the site will be sitting idle, and it is understandable that the contractor might attempt to pressure you to shorten the waiting period. **DON'T DO IT**! Explain that it might be a delayed shot. And on the matter of costs, you might point out what the costs could be in the terms of compensation claims and shutdown by the authorities while they investigate, should an accident or violation occur.

Every misfire should be followed up in an effort to identify its cause, and steps taken to prevent a recurrence.

Without doubt, the best method of dealing with misfires is to avoid them, by following those proven practices which all but eliminate their likelihood.

Notes:-

Chapter XI

Mudcapping

In some cases it may be impractical to drill a hole for explosives. The costs of bringing in drilling equipment and/or the labor costs may be too high with consideration to the job at hand. In other cases it may be impossible to drill a hole, such as when blasting steel-plate. The equipment necessary for rock-drilling may be unavailable or, the blasting target may be situated in a position that even if a hole were dug for the charge, there would be little or no confinement provided, such as in the case of the boulder or a stump sitting on the surface of the ground.

In such instances we can resort to a technique which is called **"Mudcapping".** It is also known by such names as, **"Adobe Blasting", "Bulldozing", "Blistering", "Plastering", "Plaster Shooting",** and **"Poulticing"**.

This technique involves placing an external charge directly upon the object to be blasted, and adding a measure of confinement and safety by covering this charge with a thick mound of heavy mud.

The disadvantage of using external charges is that because of the lack of confinement more explosives are required than would be necessary to do the same job with a well confined charge. Much of the energy of the explosive is wasted. And, to compensate somewhat for the lack of confinement, a higher velocity, and higher cost, explosive is usually used.

Despite these added costs, **"Mudcapping"** may be more economical than bringing in drilling equipment for a small job, or spending many man-hours drilling by hand. Even on large jobs, the costs of drilling usually greatly exceed the costs of the explosives and other blasting supplies.

The most efficient method of mudcapping is to remove the dynamite from the cartridge wrapper, and pack it into a compact conical mound directly on the spot where the explosion will do the most good. Then, the cap is inserted directly into the mound, and is covered with the cartridge wrappers. Finally, a thick, heavy mud is packed into a mound on top of the explosives. This mud should be about 12-inches deep. Great care should be taken to make sure that this mud doesn't contain rock-fragments or other hard objects which could become dangerous missiles when the blast is fired.

Obviously, the principle behind capping the external charge with a layer of heavy mud is that the mud serves to confine the charge and direct more of the explosive energy toward the target than would otherwise be the case. Less energy is wasted, and more work is accomplished. And, safety is improved because the mud protects the explosives from the impact and accidental ignition.

For the best results in mudcapping, one of the higher velocity explosives should be used. One with good shattering capabilities.

Below we illustrate two mudcapped charges. One on a stump with shallow, exposed roots, and the other on a boulder. The former would be placed in a deep crotch between two solid roots, and the latter on a fissure, crack or indentation, if possible

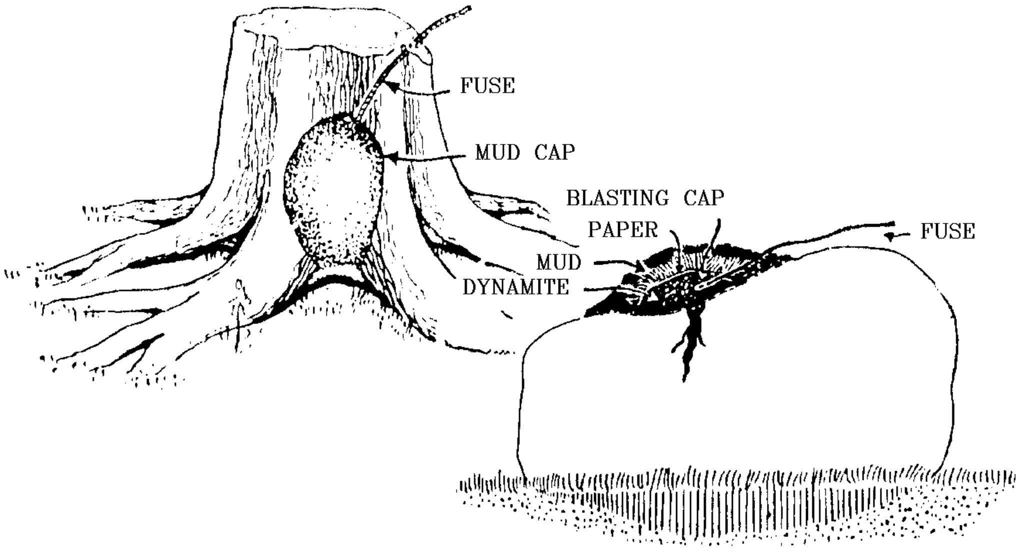


Fig. 89. "Mudcapping".

There are some blasters who feel that it pays to rest the explosives on top of a layer of mud, in addition to covering the charge with mud.

Mudcapping is a method which can be used successfully for blasting any exposed material, without the necessity of a shothole. It is extremely noisy, however, and this and the danger of fly-rock make it unsuitable for use in built-up areas.

Mudcapping is also used in secondary blasting, in reducing the size of products produced by a conventionally confined primary blast.

Whenever you use an externally-placed charge it is a good practice to **"Mudcap"** it. This is more efficient and safer than resorting to an entirely exposed external charge.

While demolition charges in military operations are seldom mudcapped, they invariably use extremely high velocity military explosives, and speed of placement is a far more important consideration than economy.

Notes:-

Chapter XII

Blasting Rocks, Boulders and Ledges

There are many reasons for removing boulders or rock ledges. They may lay in the path of a proposed right-of-way such as a road, pipeline, ditch, or powerline. They may be in land under cultivation or which is being prepared for cultivation. Large pieces of rock may remain after a large blast, and these must be reduced in size before they can be utilized or hauled away. Or, rocks or ledges may have to be removed for other construction or property-development purposes.

Large rocks and boulders can usually be broken and removed more quickly and economically through the use of explosives than any other means.

The results desired may vary from job to job, and so the blaster must be prepared to vary his/her techniques and loadings. For example, if he/she were removing a boulder from a field being cleared for cultivation, he/she would ideally lift it from the ground and break it into pieces which could easily be hauled away. Excessive fragmentation would throw chunks of the rock over the area and leave pieces in the ground, all of which would then have to be removed.

On the other hand, if the boulder was being removed from a road right-of-way/allowance, he/she may desire a high degree of fragmentation. The broken rock may be useful or even necessary as fill or ballast, and if some was scattered about or left in the ground below grade it would not pose a problem. This would be more desirable than lifting the whole rock from the ground and being left with a hole to refill.

In short, the blaster must use his/her head and decide just what he/she wishes to accomplish, and plan the job accordingly.

There are four methods commonly used in blasting rock boulders and outcroppings. First, we have the **"Mudcapping"** method which was described previously, in which an external charge is placed on the boulder and covered with a mound of heavy mud. The second method is **"Blockholing",** in which a hole is drilled into the rock, which is loaded and stemmed and fired. The third method is **"Snakeholing",** in which a hole is dug or punched **under the target**, which is loaded, stemmed and fired. And the fourth method is used when we are lucky enough to find a suitable crack or seam in the boulder or ledge. It is called **"Seam Blasting",** and consists of loading and stemming or mudcapping explosives into a seam or crack which already exists.

The method selected will depend upon a number of factors including the equipment at hand, the depth of the rock in the earth, whether it is desired to remove the rock more or less intact, and others.

NOTES:-

Mudcapping is discussed in a previous chapter, and will not be covered again, here. The illustration below should refresh your memory on this technique.

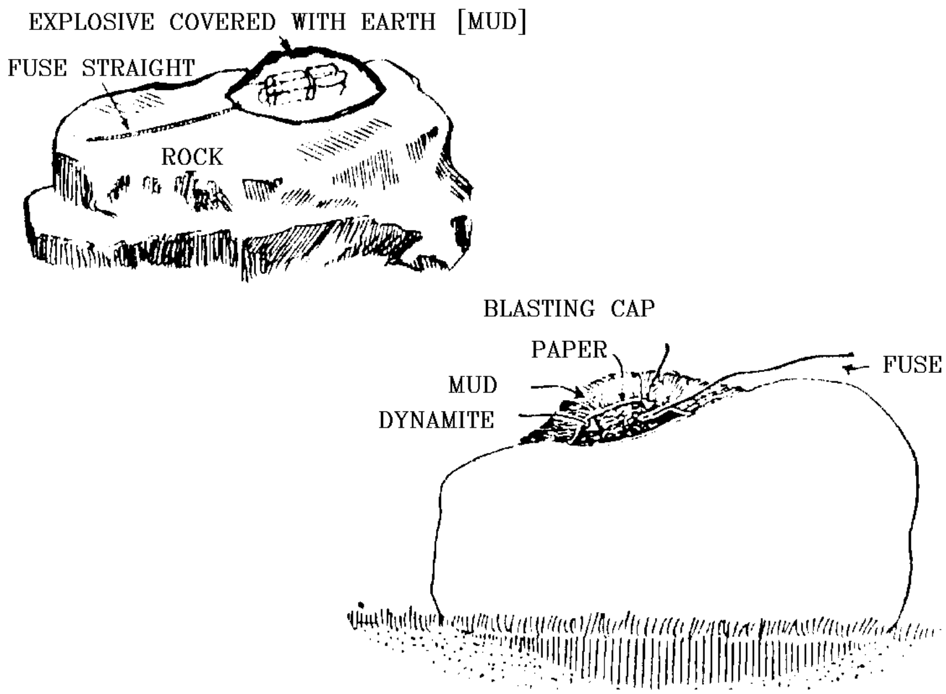


Fig. 90. "Mudcapping".

In placing a mudcapped charge, look for a spot on the target where you would strike it with a sledge if you were attempting to break it by hand. With a little experience you will learn to identify the spots on which to position your charges.

When a stone is more than four feet thick, the best results are usually obtained by using two or more mucapped charges, which must be fired simultaneously. Obviously, the firing of two or more charges simultaneously cannot be achieved with cap and fuse firing methods!

Keep in mind that mudcapping is noisy and generally produces many flying fragments. Accordingly, it is seldom suitable for use in built-up areas.

On the other hand, it is the fastest method, and no time, energy or expense is devoted to filling holes.

<u>Notes:-</u>

When **“Blockholing”** we drill a hole into the rock which is slightly larger than the diameter of the cartridge we are using. This hole should penetrate approximately half-way through the boulder, as shown below.

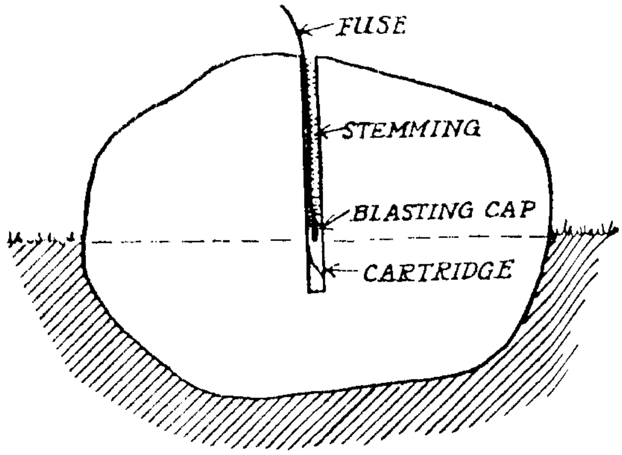


Fig. 91. “Blockholing”.

While cap and fuse firing is shown here, electric firing methods may be used. If more than one charge is involved on the same target, which may be a desirable if the rock is over six feet in length, then electric or detonating cord firing systems must be used to insure the simultaneous detonation of all charges.

The principal advantage of “Blockholing” is that it requires the smallest amount of explosives to do the job. The principal disadvantages are that it is often impractical to bring in power drilling equipment for a small job, and labor costs in drilling may exceed the cost of the extra explosives used in other methods. Also, if the rock is deeply imbedded in the soil, large chunks of it may be left under the surface, which may be undesirable in much agriculture and property-development blasting.

A hand **“Star Drill”** may be used to drill the hole in a small rock-blasting job, however, hand-drilling is very time-consuming and is usually impractical unless time is unimportant.

The **“Snakeholing”** method is probably the most common method used in boulder blasting. It offers advantages over both mudcapping and blockholing. No rock-drilling is involved, yet the charge may be well confined and less explosives needed than when mudcapping. However, it requires a little more work than mudcapping.

Another advantage of **“Snakeholing”** is that since the charge is located directly under the boulder, it serves to lift it out of the ground and break it up at the same time.

NOTES:-

Below, we illustrate one method of snakeholing. You will note that in this case the hole has been dug under the boulder, the explosives placed in a compact mound directly under the boulder, resting against the rock and preferably situated at the point of greatest resistance, and the hole has been refilled.

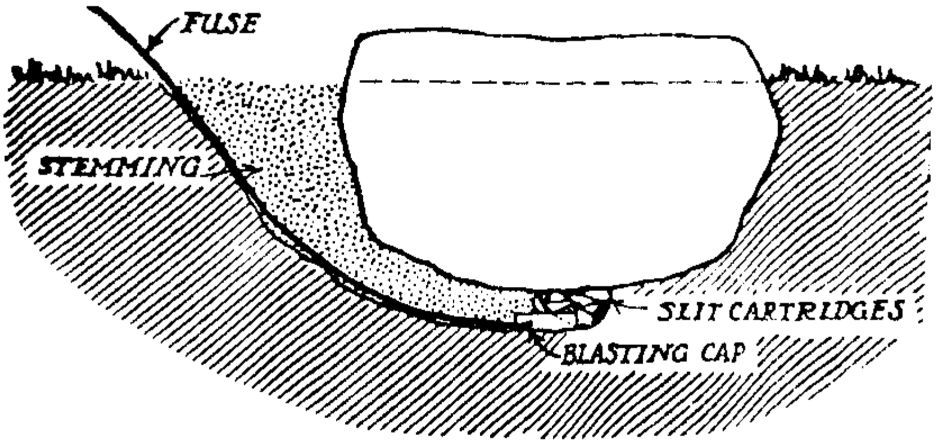


Fig. 92. "Snakeholing".

A narrow trench about the width of your shovel is all that is needed in burrowing under the rock. After the explosives are placed and primed this trench must be refilled and tamped to provide good confinement. Ideally, the stemming should be as firmly tamped as the surrounding earth. Wetting the material as it is packed in will help to accomplish this.

It is important that the explosives be situated directly against the bottom of the boulder, and approximately at the center of the balance, so the boulder will lift evenly.

The common practice in snakeholing is to "Direct-Prime" the charge. That is, to load the primer cartridge last, with the base of the cap pointed toward the bulk of the charge.

When working with very large boulders or ledges, more than one charge should be placed underneath. When this is done all charges should be fired simultaneously, and this calls for electric or detonating cord firing systems.

Snakeholing is probably the easiest and most successful method of boulder blasting. However, it is not very effective when blasting rocks laying on the surface! Too much of the power is lost because of poor confinement. In such cases it is better to blockhole or mudcap.

Occasionally, snakeholing may roll the boulder out of the ground onto the surface without breaking it sufficiently. When this happens, the rock can be further fragmented by mudcapping.

Not being especially fond of digging, the writer prefers a slightly different method of snakeholing when practical. Using a driving iron, we punch an angled hole under the rock. Then we **"Spring"** this hole with a small springer charge. After allowing ample time for the hole to cool, we load our main charge into the cavity formed by the springer, stem and tamp it well, and fire it. This requires less work in both digging and stemming!

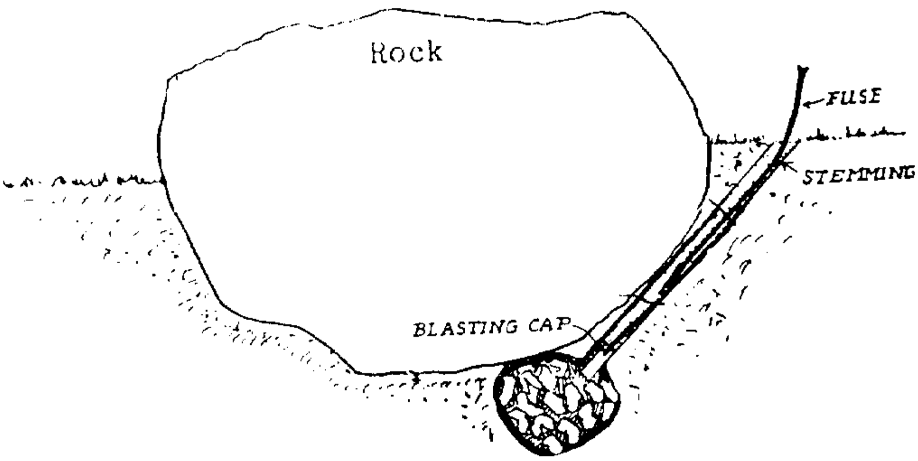


Fig. 93. "Springing a Snakehole"

"Seam Blasting" consists of loading explosives directly into a deep seam or crack which already exits in a rock or a ledge. If a crack or seam can be found which is one-half inch or more in width and reasonably deep and well situated it may be cleaned of earth and stone chips and loaded. It should be loaded as deeply as possible, packed well, and then further, confined by mudcapping. However, if the rock is very fractured or seamy, it is unlikely that good confinement will be possible.

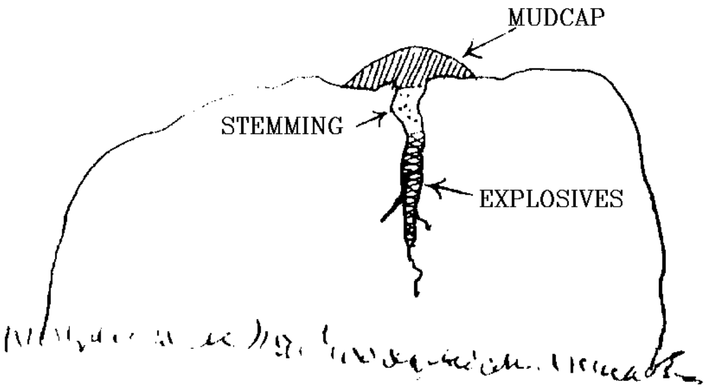


Fig. 94. "Seam Blasting".

NOTES:-

Below we illustrate ledge-blasting by the blockholing and snakeholing methods.

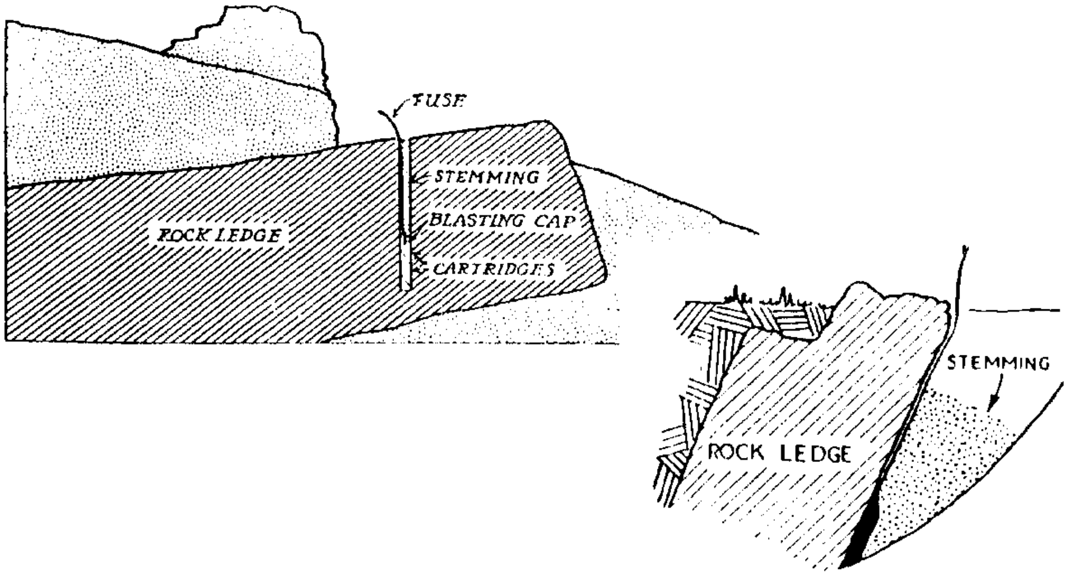


Fig. 95. "Ledge-Blasting by Blockholing and Snakeholing Methods".

When necessary mudcapping can also be used in ledge blasting. However, in the case of a wide ledge, blockholing with a series of drillholes, or snakeholing at a number of points along the ledge, are preferable.

It is obvious that the hardness, density and the fracturing characteristics of rock varies. For this reason, it is impossible to provide a hard and fast loading table which will be satisfactory in all instances. Only general guides for loading can be presented, and the shooter can use these for test-firings and then add or subtract explosives based upon the results achieved. Generally, a blaster can be expected to quickly learn the characteristics of the rocks and formations in his/her area, and vary his/her loadings according to his/her experience.

When snakeholing, we use 1 - 2 cartridges per cubic foot of rock to be broken. When mudcapping, we use the rough formula of 3 - 6 cartridges per cubic foot.

The table which follows shows suggested charges for blasting boulders by various methods.

[40% Extra Dynamite, 1 1/4" X 8" Cartridges]

Thickness of of Boulder Opp. Charge	Cartridges Mudcapping	Cartridges Snakehole	Cartridges Blockhole
1 1/2 Feet	1 - 2	1	1/4
2 Feet	2 - 3	1 1/2 - 2	1/4
3 Feet	4 - 5	3 - 4	1/2
4 Feet	6 - 8	5 - 7	1

Fig. 96. Tables for Blasting Boulders.

It is necessary on occasion to blast boulders or rock formations near a building. In such cases, mudcapping is usually out of the question because of fly-rock. Using blockholing or snakeholing methods, blasting mats or a number of logs or timbers chained together over the charge will reduce both noise and missiles.

However, very often such blasting is to be followed by filling and leveling and in such cases confinement can be added and noise and missiles reduced by dumping a load of rock-free fill, of dirt, onto the charge after loading it. After the blast the remaining dirt can be spread around to fill and level the area.

In summarizing, **"Snakeholing"** is the preferable method of boulder blasting when the boulder is deeply imbedded and/or you wish to remove it entirely. **"Mudcapping"** is best when the boulder is laying on the surface, and when drilling is impractical or impossible. And, **"Blockholing"** is preferable on surface rocks where large numbers of such rocks makes it practical to bring drilling equipment.

As previously indicated, in planning a rock-blasting job the blaster has more to consider than merely demolishing rock. He/She must consider related aspects, such as whether he/she wants to produce rock-fill, whether or not all rock must be removed from the ground, the equipment at hand to haul away the fragments, and so forth. Successful boulder blasting is completing the entire job, clearing, refilling, carting off fragments, etc., with a minimum of time, money and effort. This calls for thought in the selection of techniques, explosives and loadings.

Notes:-

Chapter XIII

Stumping with Explosives

In many development and construction projects it is necessary to remove tree-stumps in the early phases. In large operations, bulldozers are frequently used to pull stumps from the ground. But, even when such heavy equipment is available mechanical stump-pulling is often unsatisfactory. The quantity of dirt remaining on the roots, and the fact that the stump remains whole, makes the stumps extremely heavy to handle and haul and very difficult to burn soil-covered stumps far exceeds the costs of the explosives which would have been required to blast them out.

Explosives are usually the most practical means of stump removal, because they break the stump into two or more easily handled pieces, and leave little or no soil clinging to the roots.

The technique and quantity of explosives employed to blast stumps varies with a number of factors, including the type and size of stump you are dealing with. For our purposes we will divide stumps into four groups or types.

The most common type of root encountered is the lateral root, examples of trees with lateral roots being White Pine, Maple, Fir, Hemlock, Cedar and Spruce. The roots are usually near the surface and parallel to it. On the next page we illustrate a lateral root.

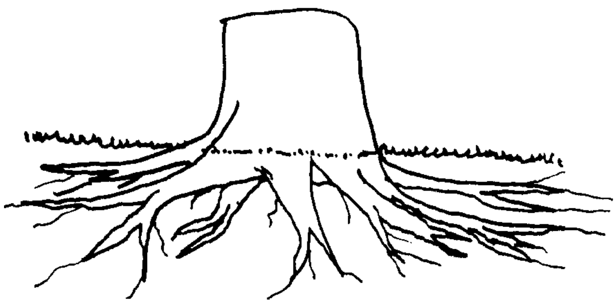


Fig. 97. "Lateral Rooted Stump, Root System".

Then we have the tap-rooted stump, which has one large main root which extends straight down into the ground. These have a few small lateral roots extending outwards, but the main root extends straight down, and looks like a very large carrot.

The best known examples of trees with tap-roots are Southern Yellow Pine, Red and Norway pine, and Hickory.

Below we illustrate a tap-root.

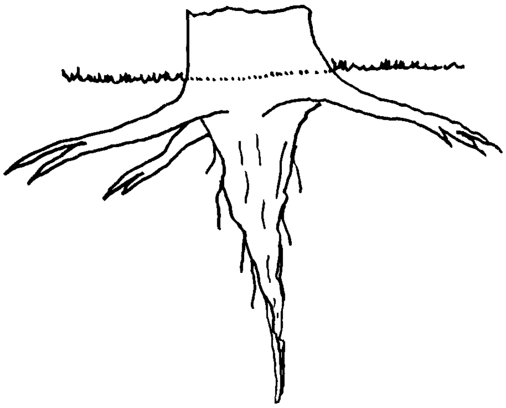


Fig. 98. "Tap-Rooted Stump, Root System".

We find some trees which have characteristics of both lateral and tap-roots, which are called semi-tap-rooted. These have several large roots which extend downwards into the soil.

It will be seen that the system resembles the lateral root system except that there are fewer and larger roots and these grow more directly downward and are much deeper.

Common examples of semi-tap-rooted trees are White Oak, Elm, Chestnut, and Gum.

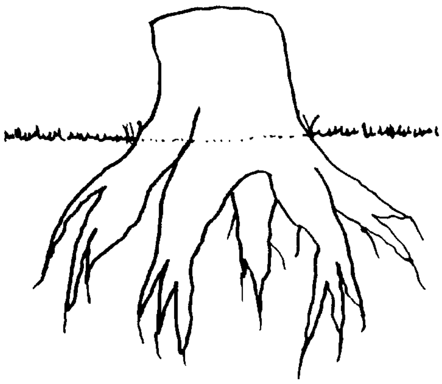


Fig. 99. "Semi-Tap-Rooted Stump, Root System".

The last group isn't really comprised of trees having a different root system, but rather stumps which because of age or other factors are extremely shallow-rooted. These were most often lateral-rooted at one time, but became partially pulled from the ground because of age, the action of frost, or livestock walking in the area.

Also, stumps of some trees growing in swampy areas are often very shallow-rooted. And, some trees such as white pine growing in shallow topsoil's over bedrock have extremely shallow root systems. A shallow-rooted stump is illustrated below.

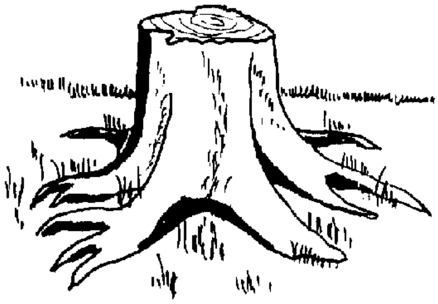


Fig. 100. "Shallow-Rooted Stump, Root System".

It is important for the blaster to recognize the type of root system he is dealing with, and whether or not the roots are approximately equally balanced or concentrated more on one side than the other. As previously mentioned, a quarter-inch diameter springy steel rod is handy for probing to learn more about a particular root system.

The blaster should be alert to the amount of decay in the stump, and the moisture content and confinement characteristics of the surrounding soil. Blasting efficiency is influenced greatly by the degree of confinement and moist soil provides better confinement than dry soil. So, best results can usually be achieved when the ground is wet. Accordingly, it is a good idea if possible, to schedule stumping for a time of the year when the ground will be wet.

Stumps which are in loose, sandy soils or gravel require more explosives than stumps in heavy soil, for two reasons. First, trees growing in light soils tend to develop deeper and more extensive root systems. And second, light soils don't provide good confinement and some of the explosive energy is wasted. So, such stumps often require heavier and deeper loadings.

On the other hand, root systems in clay, heavy or wet soils tend to be more shallow and less firmly anchored and better confinement is afforded. Consequently, less explosives and shallower charges are required.

Another factor the blaster must consider is the age and amount of decay in the stump. Green stumps require much heavier loadings than aged stumps.

In selecting explosives for stumping, you are on safe ground to select one which has been designed by the maker as a **"Stumping Dynamite"**, such as DuPonts 40% Extra Dynamite. You want a product with a relatively low speed and good heaving or lifting characteristics. If the soil is very light and sandy you may get better results using a 60% Extra Dynamite, but don't use a faster product than is necessary as these tend to shatter the stump into numerous pieces, some of which may be left in the ground!

When stumping, you should carry an ax and a chisel-bar as well as loading pole, punch bar, sledge, and spoon, shovel or soil auger. If working with deep tap-rooted stumps you may also need a wood auger.

As when snakeholing rocks, you should place the explosives under the point of greatest resistance. When placing single charges these are not necessarily directly centered under the trunk, but are rather placed with consideration to the root system. Keep in mind that it is the anchoring of the roots and not the weight of the stump which offers the resistance. Imagine yourself a giant, about to push the stump out of the ground with one finger. Where would you place that finger in order to push that stump from the ground evenly? This is where you would place the explosives.

Of course, you can't look down into the ground and see the root system such as they appear in our drawings. But, after a little experience you will often have a good idea of the root system of a particular tree by examining it and probing.

In some cases, more than one charge may be needed, in which event electric or detonating cord firing systems must be used to achieve simultaneous detonation of all charges.

But, cap and fuse firing is most common in stumping. For some reason, however, people seem prone to short-fuse when stumping. **This is dangerous and false economy**! **Under no circumstances should the fuse extend less than 24-inches from the collar of the hole**. Preferably, it should extend 30-inches, or more if laws require.

Note:- Canadian Laws require that you use a minimum fuse length of 6-feet and most Provinces follow those regulations.

Most stumping requires small charges, and for a reason which escapes us, some blasters tend to become careless and ignore many safety practices when small shots are involved. This doesn't make sense, because one cartridge is more than adequate to kill or maim. Follow the same precautions when handling one cartridge as when handling twenty cartridges. One cartridge should be stored, transported, handled and used with the same care and compliance with safety rules as a whole case.

Let's examine the loading of an evenly-rooted lateral root stump.

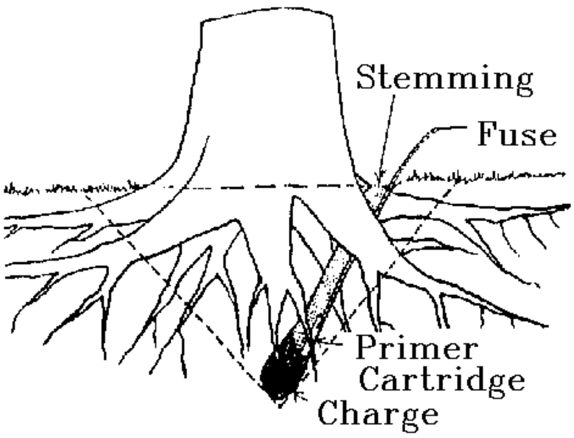


Fig. 101. "The Loading of an Evenly-Rooted Lateral Root Stump".

Note that an angled hole has been punched to a point directly under the stump. To a point slightly deeper than the main root system. [**If it were placed too shallow, the roots might be broken off instead of being pulled out, and the stump might be split, but not blown from the ground!]**

Note, also that the charge is tamped and the hole is stemmed. And, the primer cartridge has been loaded last!

NOTES:-

In the drawing which follows we show the loading of an unevenly rooted stump. The charge has been placed off-center to compensate for the heavier and stronger roots extending from the one side.

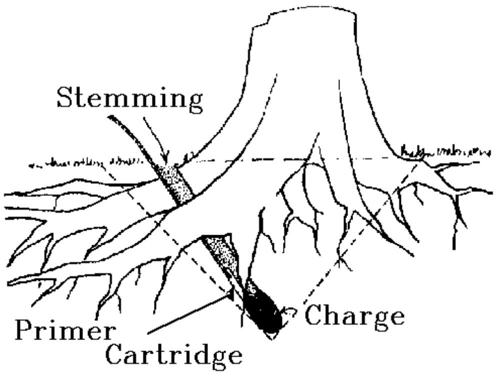


Fig. 102 "Unevenly Rooted Lateral Root Stump".

When blasting large, heavily rooted stumps with either lateral or semi-tap roots, you may use either a single sprung-hole charge or several charges distributed around the stump. First, let's examine the single sprung-charge.

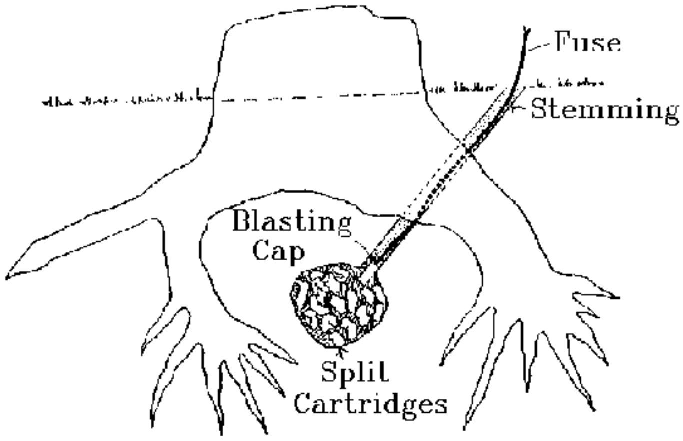


Fig. 103. "Sprung-Charge".

After the hole was punched, from one-eighth to one-half a cartridge was placed in it and fired without stemming. This formed a pocket large enough to hold several pounds of explosives.

In the drawing below, we illustrate the loading of a large, heavily-rooted stump with a number of distributed charges. Note that the electric firing method has been used, to achieve instantaneous detonation of all charges. And, when placing multiple charges, one charge is often placed directly under the trunk area to split and lift it, and other charges placed under the heaviest roots.

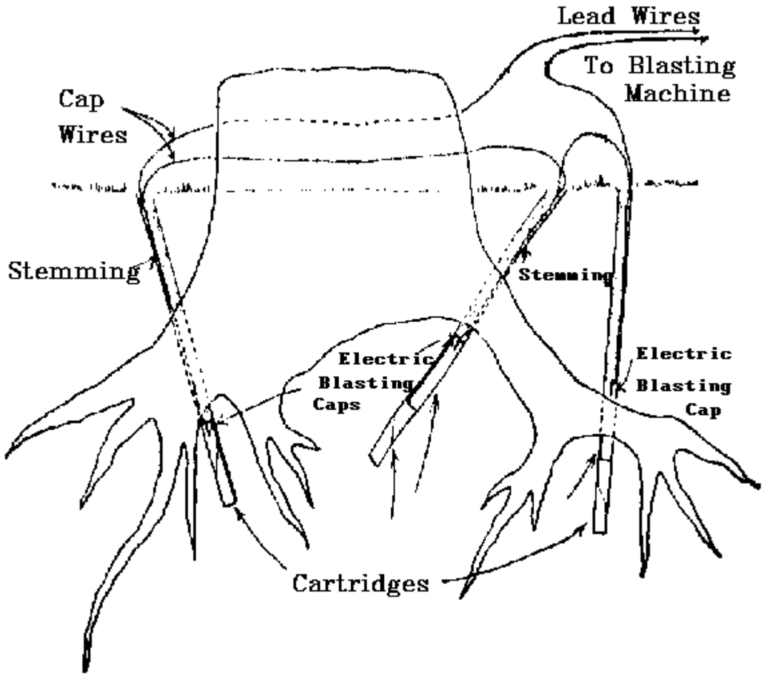


Fig. 104. "Large Heavily-Rooted Stump With a Number of Charges".

Tap-rooted stumps may be removed by one of the three different methods. In the first shown below, a hole has been drilled to a point just beyond the center of the root, and this loaded, stemmed and fired. In the second, one heavy charge is placed against the root. This is placed so that its entire energy is directed against one spot on the root, to sever it and throw it from the ground.

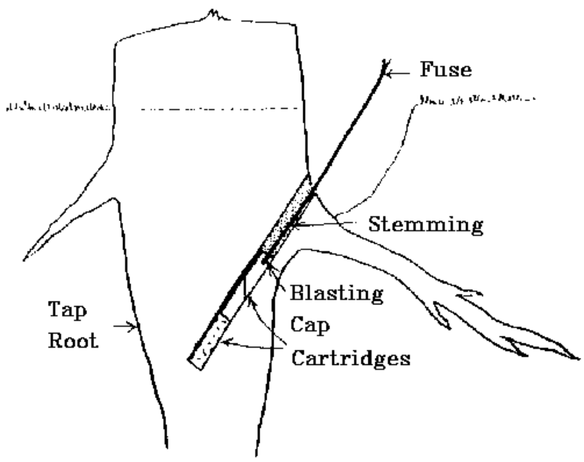


Fig. 105. "Tap-Rooted Stump, Drilled and Stemmed".

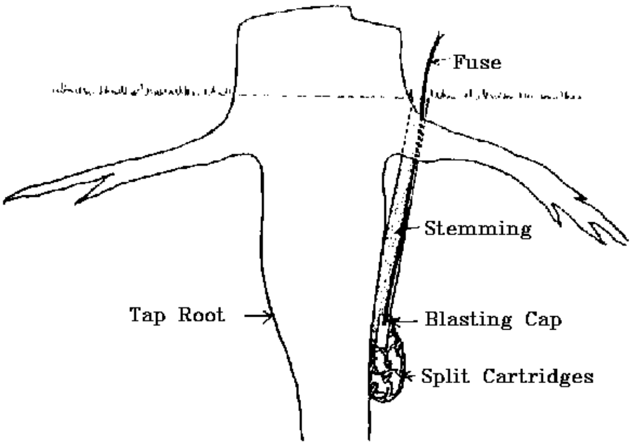


Fig. 106. "Tap-Rooted Stump, With Charge Placed Against The Root".

NOTES:-

The third method consists of placing two or more smaller charges against the sides of the tap-root, three feet or more below the surface. The holes are made with a bar or earth auger directly alongside the root, and loaded with columns of explosives.

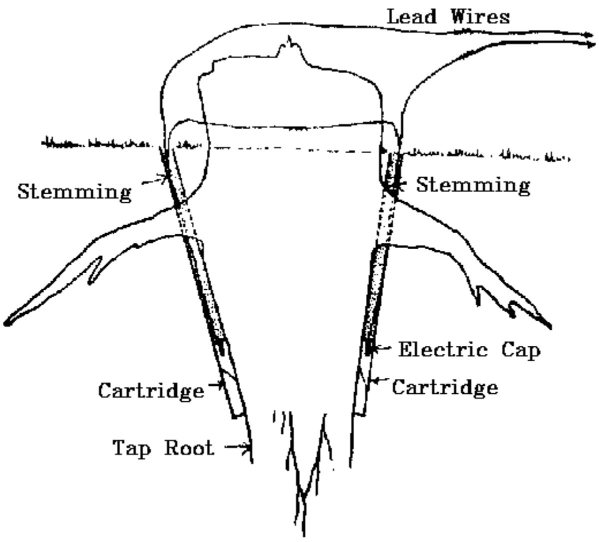


Fig. 107. "Tap-Rooted Stump, With Loaded Column Charges".

When using any of the previously described methods of blasting a stump which is situated on the side of a hill, the charge or the majority of the charges should be located on the uphill side of the root system.

Extremely shallow-rooted stumps laying on the surface can be best handled by mudcapping, which tends to split the stump, especially if the charge is in a crotch, and the old shallow roots are easily torn from the ground.

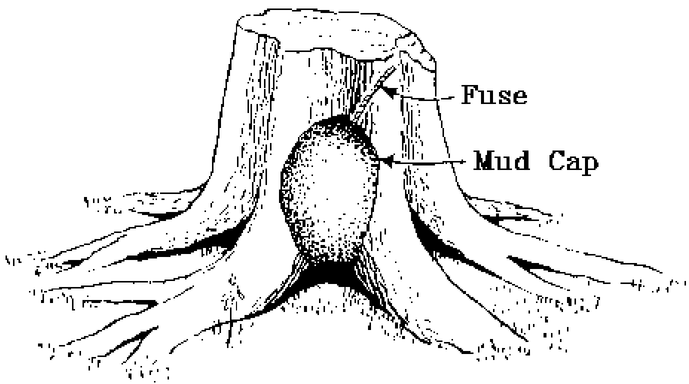


Fig. 108. "Extremely Shallow-Rooted Stump Laying on the Surface".

Another type of stump which requires special handling is one which is hollowed out. It may have rotted in the center, or have been burned, or it may be one of the variety of trees which tend to become hollow. In any event, a single charge located directly beneath it will usually cause it to split so easily that much of the energy will escape and the halves will tend to hinge-back rather than be lifted out. Accordingly, when dealing with hollow stumps, even small ones, it is a good practice to use at least two charges, as shown below.

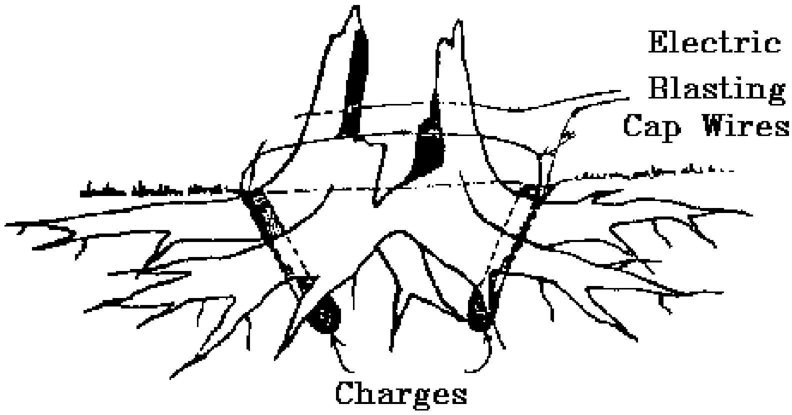


Fig. 109. "Blasting a Hollowed Out Stump".

It was mentioned previously that when multiple charges are involved, electric or detonating cord firing systems should be used in order to insure the simultaneous firing of all charges. Below, we illustrate how a firing circuit with detonating cord could be laid-out. Note the complete **"Circuit"** through which the detonating wave can travel in both directions, thereby reducing the chances of a misfire.

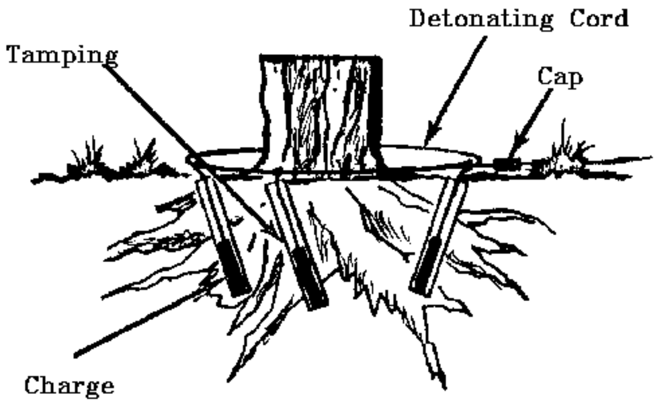


Fig. 110. "Detonating Cord Layout for Stump Removal".

<u>NOTES:-</u>

Because of the many variables, it is impossible to provide a loading table which would be suitable in all instances. The following table shows loadings which prove satisfactory under average conditions, and will serve as the basis for making trial shots. Loadings could then be adjusted up or down, depending upon the results of test-firings and experience.

No. 1 1/4 X 8" Cartridges

Diameter of stump one foot above ground	**Green**	**Old**	**Partly Rotted**
6"	**2**	**1 1/2**	**1**
12"	**4**	**3**	**2**
18"	**6**	**4**	**3**
24"	**8**	**6**	**4**
30"	**10**	**7**	**5**
36"	**13**	**9**	**6**
42"	**16**	**12**	**8**
48"	**20**	**15**	**10**

Fig. 111. "Tables For Stumps. Diameters vs Cartridge".

These loadings are based upon a 40% strength dynamite. Increase for light or dry soils. Decreased by at least one-half when charge is loaded into a hole drilled into a tap-root, and stemmed.

This table does not apply to the extremely large stumps found in the **Pacific Northwest**, which are often shot while green in logging operations. Special fast and powerful stumping explosives are sold only in that area to meet their particular needs.

There, the diameter of the stumps is taken 4-feet from the ground, and the formula for green stumps of Fir or Hemlock is one cartridge per inch of diameter. Loadings are reduced by one-half for old but firm stumps. For Spruce, loadings are reduced by one-half and for Maple, Alder and Cedar they are reduced by approximately one-third.

Notes:-

Chapter XIV

Cutting Timbers, Pilings and Trees

Explosives are used frequently to cut wooden timbers, beams and pilings both on dry land and below the surface of water. There are circumstances under which this may be the only practical means of severing wooden members. In other cases, it may be more practical to do so by manual or mechanical means such as sawing.

Three methods are commonly used. Placing one or more internal charges in a hole or holes drilled into the target. Using one externally-placed charge, or utilizing two balanced and opposed external charges.

High velocity explosives such as 60% to 80% Special Gelatin or Nitroglycerin Dynamite do the best job in timber cutting.

If a single charge is involved, it may be fired with cap and fuse, but where the simultaneous detonation of two or more charges are involved electrical or detonating cord firing is required. If blasting underwater, detonating cord systems are best.

The advantage of internally placed charges is that a much smaller quantity of explosives is needed than is the case with external charges. The disadvantage is that more time and effort is required to drill. And, it may be impossible to drill.

A hole about 1 1/2 inches in diameter is bored with a wood auger to approximately two-thirds through the timber. If the timber is un-even in thickness, the hole should be made to run parallel with the greatest dimension. The appropriate charge is loaded, tamped for maximum density, and tightly stemmed.

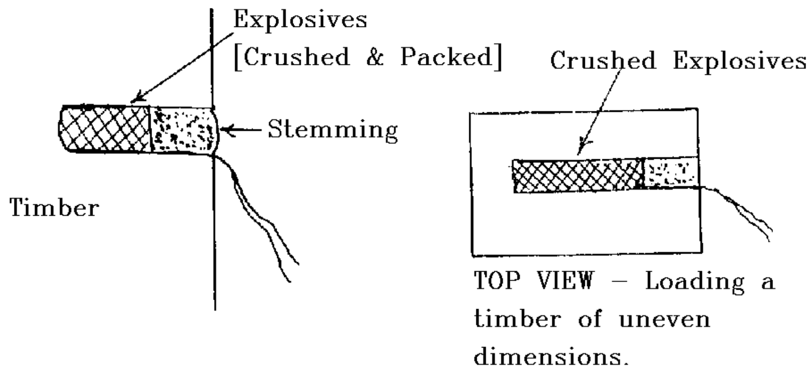


Fig. 112. "Timber Blasting".

If a single hole will not hold the quantity of explosives required, a second hole at right angles to the first should be drilled and loaded, as shown below.

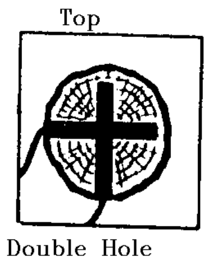


Fig. 113. "Double Hole Timber Blasting".

Optimum loadings will vary with the density, strength, age and degree of deterioration, of the wood, and other factors. However, to calculate an internally-situated timber-cutting charge we use the formula:

$$P = \frac{D^2}{250}$$

Where **"P"** is the number of pounds of high velocity explosives **"D"** is the diameter **[or least diameter or least dimension of an uneven timber]** and **"250"** is constant.

Thus, the amount of explosives required to cut a 15-inch diameter timber using a tamped internal charge is calculated;

$$P = \frac{15^2}{250} = \frac{15 \text{ X } 15}{250} = \frac{225}{250}$$ **- 0.9 Lb., so we'd probably use 1 Lb.**

Since 1 1/2" X 8" cartridges of the type recommended weigh about one-half pound each, two cartridges would be the load to use in the above case under average conditions.

For the reader's convenience we show recommended loadings in the Table below which are arrived at by the above formula. Again, diameter refers to the least dimensions of the target.

Diameter of Timber	**Approximate Internal Loading**
10"	**0.4 Lb., or 1 Cartridge**
15"	**0.9 Lb., or 2 Cartridges**
18"	**1.3 Lb., or 3 Cartridges**
24"	**2.3 Lb., or 5 Cartridges**
30"	**3.6 Lb., or 7 Cartridges**
36"	**5.2 Lb., or 10 Cartridges**

Fig. 114. "Tables for Loadings By Diameter of Timber".

Sometimes it is impractical or impossible to bore holes in timbers. In such cases an external charge may be used even though more explosives will be needed to do the job.

To use a single, externally-placed charge, we tie, tape or suspend the required loading around the timber at the point we wish to cut it. No drilling, tamping or stemming is required.

Below we show an external charge in which cartridges have been tied to the target. They should be held tightly against the timber, and all cartridges touching. They may be strung either side-by-side or end-to-end.

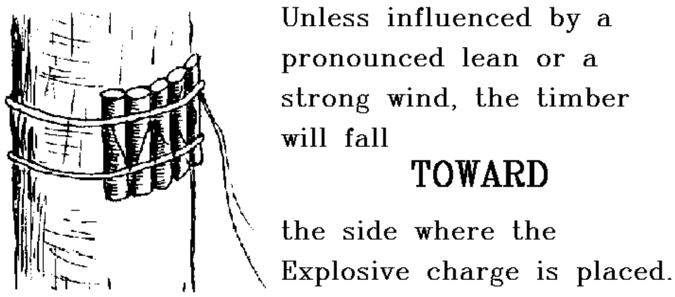


Fig. 115. "External Charge with Cartridges Tied to the Target".

The quantity of explosives required to cut timbers with external charges is calculated by the formula:

$$\mathbf{P = \frac{D^2}{40}}$$

Where **"P"** is again the quantity of explosives in pounds, **"D"** is the least diameter or dimension of the target, and **"40"** is constant.

So, you'd calculate the quantity of explosives to cut a 20-inch timber by external charges as follows:

$$\mathbf{P = \frac{20^2}{40} = \frac{20 \text{ X } 20}{40} = \frac{400}{40} = 10 \text{ pounds}}$$

<u>Notes:-</u>

In the table which follows we show some loadings derived through this formula.

Diameter of Timber	**Approximate External Loading**
10”	**2.5 Lb. or 5 Cartridges.**
15”	**5.6 Lb. or 11 Cartridges.**
18”	**8.1 Lb. or 16 Cartridges.**
20”	**10 Lb. or 20 Cartridges.**
24”	**14.4 Lb. or 29 Cartridges.**
30”	**22.5 Lb. or 45 Cartridges.**

Fig. 116. “Tables Derived Through The Above Methods”.

When working with timbers of uneven thickness, you are advised to place the charge on the widest face, so that the cut will be through the least dimensions.

And, consider using a flexible detonating cord for tying material, since this also adds certainty to a good high-order detonation of the entire charge.

When a timber is to be cut at a point below the surface of water, or down in an excavation, the charge may be lowered into place from the surface. Detonating cord may be used to both form the loop which holds the explosives and to lower and fire the charge, as shown below.

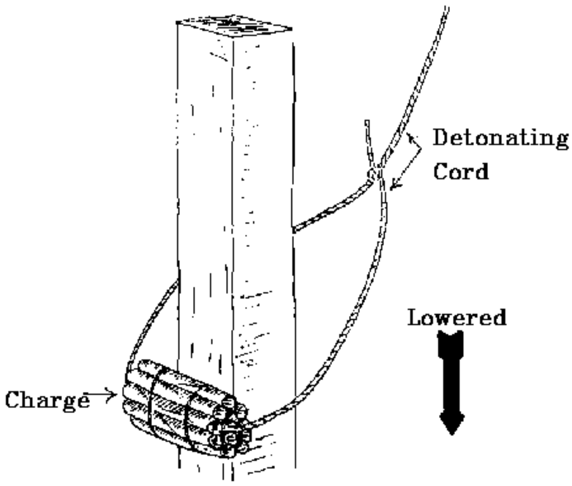
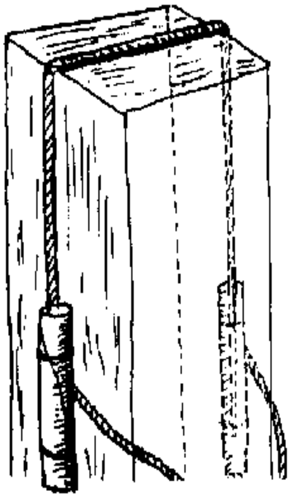


Fig. 117. “Using Detonating Cord to Hold the Explosives & to Lower and Fire the Charge”.

The third method of timber cutting is utilizing **OPPOSED** external charges, useful only on timbers and other targets which are more or less square. We take advantage of what is termed **“Counter Force”.** The simultaneous firing of two charges directly opposite each other on the target causes the shock wave to meet at the target center. This internal meeting of shock waves causes more internal damage than would be obtained with a single charge or two charges not directly opposite each other or not detonated simultaneously.

The size of the charge is calculated by the formula for determining external charges. But then this charge is divided into two halves, and the halves are placed on the timber diametrically opposed. It is imperative that the charge is equally divided, that the charges are directly opposite one another, and that both charges are fired at the same instant.

The charges may be tied in place, held in place by a frame or propped with boards or poles, or hung from the top of the target by rope or detonating cord as shown.



If detonating cord is used, make sure the lengths of cord leading to each charge from the trunkline are identical to insure exact simultaneous firing!

Fig. 118. "Charges Hung from the Top of the Target by Rope or Detonating Cord".

It is usually impractical to cut standing trees with explosives, as this operation can almost always be more readily and economically performed with ax and saw. This applies to both cutting the tree, or attempting to blast roots, tree and all out of the ground in one operation. However, there may be occasions when this is desirable, such as in blasting a fire-break to stop a forest fire.

Notes:-

Loadings and formula are the same as for cutting timbers and pilings, although these may prove to be light with some varieties of green trees. Internal loading is illustrated below:

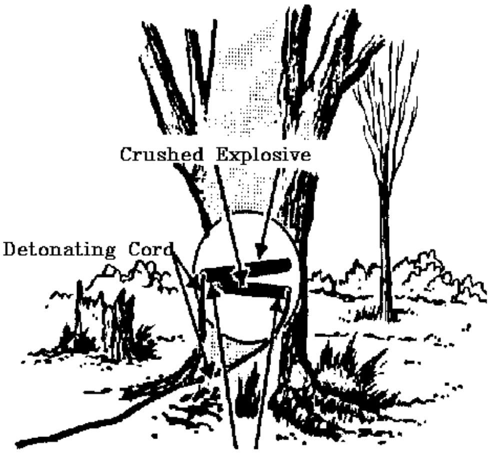


Fig. 119. "Internal Loading for Cutting Green Trees".

Notes:-

Chapter XV

Ditch and Pond-Blasting

Under reasonably favorable conditions, explosives can be economically and efficiently used in ditching. Explosives can be used when mechanical methods of ditching are either impractical or impossible.

Frequently, ditches must be made under extremely wet conditions or in rough country which is impassable to heavy machines. And, there is often no substitute for explosives when ditching under emergency conditions such as to prevent or relieving flooding.

One great advantage of ditching with explosives is that when properly done there are no spoil-banks along the ditch. Earth from the ditch is thinly spread over a large area by the blast, not left where it must be hauled away. And, the configuration of ditches produced by blasting is close to ideal for agricultural purposes.

Ditching with explosives isn't always practical. The greatest economy can sometimes be achieved through the use of digging machinery, especially when conditions are favorable for machinery and unfavorable for blasting, such as when the work is to be done in dry, loose sand or gravel. On the other hand, dynamite is especially practical and efficient when the work is done under extremely wet conditions.

Under most soil conditions ditches with depths of up to 12-feet and widths to 40-feet can be readily blasted. Large and expensive machinery is required to dig ditches of such size.

As far possible, an open-top ditch should have such an amount of fall, or grade, that a slow steady flow will be maintained throughout its length. Too much grade, and the sides may be washed away. Too little, and it won't drain adequately. The proper size and grade of ditch will adequately carry off surplus water, and tend to keep itself cleaned out.

Under most conditions, the best kind of open ditch for farm lands is a wide ditch whose banks and sides, and where possible its bottom, are grass covered. The grass roots will protect the soil from erosion. The sides should slope at about 45 degrees.

A single charge or a series of independently fired charges will not make a ditch! If you fire a single charge in the earth it makes a crater like an inverted cone, as illustrated.

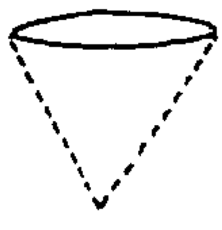


Fig. 120. "Inverted Cone of Crater Left by a Single Charge".

If a series of charges are placed in a row and fired one at a time, the result is a series of such over-lapping inverted cones. Much of the material will fall back into the holes and make an uneven and unsatisfactory ditch.

However, if all the charges are set off at the same instant, the overlapping material is carried off by the blast and a complete trench is formed. In other words, a ditch is made by interaction of a number of instantaneously fired charges!

Obviously, the object is to blow the material away from the ditch, not merely to displace it momentarily and have it fall back. When a proper ditching shot is made, the blast material is usually thrown 100 to 200 feet in the air, and is spread 100 feet or more on either side of the ditch. Cross-winds play an important part in the spreading of the material. And we often time ditching shots to take advantage of heavy cross-winds.

The line on which the ditch is to be blasted should be staked-out every 25 to 50 feet. The line, and the placement of the charges, should not be left to the eye. Measurements for the placement of shotholes should be made with a tape or measuring stick. This is especially important when propagation-firing.

If there are any trees, branches or brush overhanging the line of the proposed ditch, these should be removed or they may partially block the throw of the material. When a stump or boulder is situated on the line of the ditch, simply load it with added explosives and blast it at the same time as the ditch. Don't blast it beforehand, as this takes more time and may interfere with the results of the ditch-blast.

The most common mistake of the novice blaster is to place ditching charges too deep. If he/she wants a ditch three feet deep, he/she puts his/her explosives three feet into the ground! But as you know, some of the energy of an explosion is directed downwards, and this practice will result in deeper ditches than planned or in charges failing to blow the entire top from the ditch. Generally speaking, the top of the last cartridge should not be deeper than one foot below the surface.

To obtain a three-foot ditch we would load a single row of holes located at 15-inch centers each with a single cartridge 4 to 12-inches away from the surface. Under normal soil conditions this loading will give a ditch about three feet deep.

In most cases you want the bottom of the ditch to be almost level, with only a gradual slope for drainage, rather than following the contour of an uneven ground surface. This must be considered when punching holes and loading. When ground surface is uneven, the loads and holes must be modified to maintain an even bottom level, as shown.

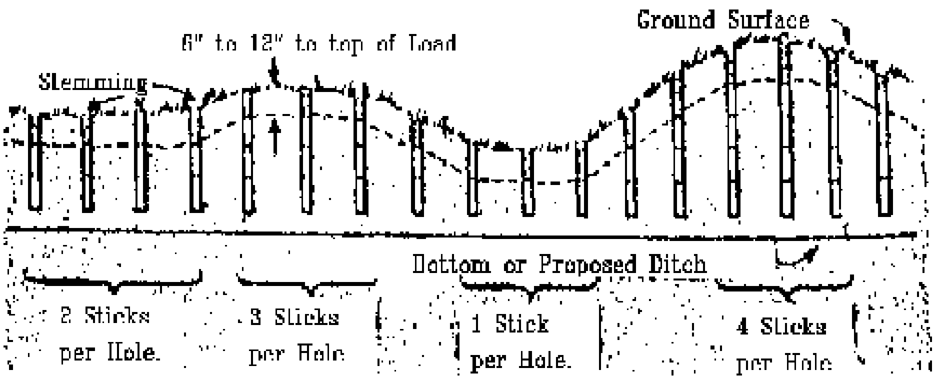


Fig. 121. "Charges Placed to Deal with an Uneven Ground Surface".

As was mentioned previously, ditching charges must be fired simultaneously. This calls for one of three choices of firing methods, Propagation, Electric Firing, or Detonating cord. By far the most economical, safest method is by Propagation, that is when only one charge is primed and fired and all the other charges in the series are fired by the concussion or detonating wave in a chain reaction.

You will recall that the requirements for propagation firing were that the material to be blasted must be quite wet, that charges must be placed close to each other, and that a sensitive explosive such as a straight nitroglycerin dynamite must be used.

Below we show a method of initiating a propagated ditching blast with cap and fuse. Note that the primed charge is not situated at the one end, but rather somewhere toward the middle of the line of holes.

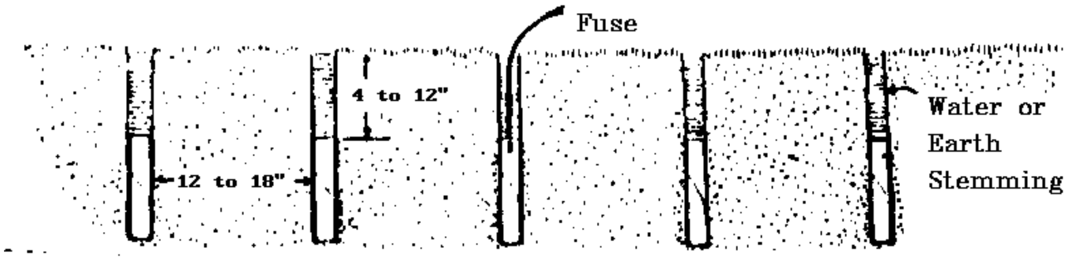


Fig. 122. "Method of Initiating a Propagated Ditching Blast".

Personally, we prefer to put an extra cartridge into the primed hole, and double-cap the primer to insure a good initiation detonation.

When propagation firing can be utilized, labor is reduced because only one charge requires priming, and there is no need to connect all the charges with wire detonating cord. This also increases the safety factor due to the elimination of large numbers of primers, and fewer blasting caps and primer cartridges on a job, the greater the degree of safety. And, the substantial decrease in time and material can save you money.

When ditching by propagation, keep in mind that stumps, logs, boulders or any other underground object can block or interfere with the transmission of detonating wave through the ground.

The advantages of ditching by propagation are so great that it is usually desirable to schedule ditching for a time of the year when you know the ground will be sufficiently wet to use this method.

When there is insufficient moisture in the soil to efficiently transmit a detonating wave, then electrical firing or detonating cord methods must be used. Each and every charge must be primed, stemmed and all fired at the same instant. The preferred method of wiring for electric ditch-blasting is illustrated below.

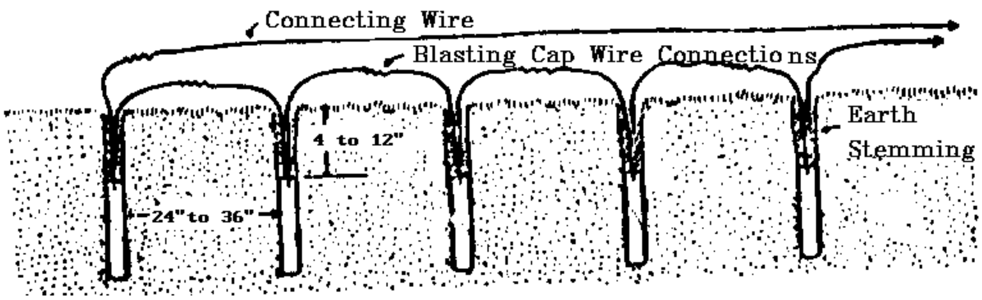


Fig. 123. "Electric Ditch-Blasting".

Note that the distance between holes has been increase, since we need not rely upon propagation. It should also be noted that in electric firing the maximum length of a single ditch-blast is limited to the capacity of the power source. Accordingly, when firing ditch-shots of considerable length electrically, large capacity blasting machines are required.

When firing by propagation 500 to 700 feet of ditch are often blasted in one shot. Greater lengths are not usually recommended because the character of the soil may change over such long distances, and the propagating ability of explosives decreases with prolonged exposure to water and no length of ditch should be loaded which will not be fired that same day. However, it is generally desirable to make as long a ditching shot as conditions permit, up to this maximum.

When constructing a long ditch, it is not uncommon to use propagation firing in those sections which are suitable for propagation, and electric or detonating cord systems in other sections. In other words, as we progress we must sometimes alter our techniques to suit changing conditions. However, it is recommended that you take advantage of firing by propagation whenever conditions permit.

As was said before, a ditch is formed by the combined action of a number of charges with overlapping blast zones. Consequently, a ditch is usually poorly formed at that place where the last charge in the shot was situated. If you were simply to load the new section in the same manner there would be shoulders and extra material left at the point where the one blast stopped and the next one began. To overcome this, we must place extra charges between the two sections as shown below:

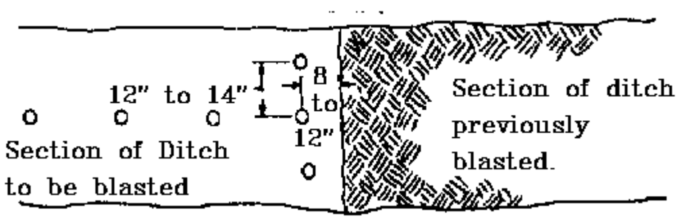


Fig. 125. "Extra Charges Between Two Sections of a Ditch".

The above drawing shows a single-row loading, but the principle of adding extra charges where one shot stops and the next commences applies to all types of loadings.

Ditching calls for a relatively strong and high velocity explosive. It must pulverize the soil material and throw it a good distance. This, and the fact that good confinement is not always possible in shallow holes necessitates the use of one of the faster explosives. And, since ditching explosives are frequently placed in wet holes, an explosive with good water resistance characteristics is needed. A relatively sensitive product is also required.

Special ditching dynamites are available which have all these characteristics, such as DuPont's **"Ditching Dynamite", which is 50% straight dynamite especially designed for ditch blasting. It is in 1 1/4 X 8-inch cartridges with about 104 cartridges to the 50-pound case**. It will be seen that each cartridge weighs about one-half pound. While ditching dynamite has the characteristics necessary for propagation firing, we recommend that it also be used for ditching by electric and detonating cord firing systems.

When large charges are located deep in the ground such as in certain post-hole loadings, and these are not being fired by propagation, a 60% extra dynamite may be substituted.

The exact amount of explosives required to produce the best results in any ditching shots will vary with a number of factors, including the nature of the soil and its moisture content. Soil composition and moisture vary tremendously from area to area and from season to season. Because of this, there is no one loading which is going to do the perfect job in all areas at all times. Recommended loadings are based upon average conditions, and may be adjusted. In making calculations to estimate the approximate quantity of explosives needed for a ditch-blasting job, we use as a rough guide the formula of one pound of explosive for each cubic yard of material to be removed.

Notes:-

Single-Line Column Loadings

The single-line column method of ditching consists of a single line of small diameter columns of explosives spaced at equal intervals along the center line of a proposed ditch. This is the most simple method of loading, and will produce ditches from about 1 1/2 to 6-feet deep, with top-widths of from 4 to 16 feet.

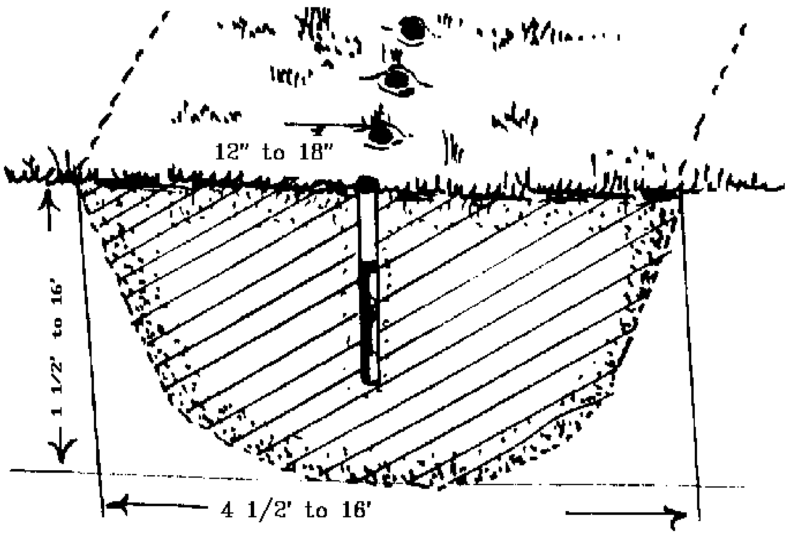


Fig. 125. "Single Column Loadings".

Small diameter cartridges are placed in holes which are from about 12 to 24 inches apart, depending upon the quantity of explosives in each. The distances suggested will insure propagation under suitable soil conditions. These loadings are with the top of the charges 6 to 12 inches below the surface. If the ground is very soft and wet, better results may be obtained by placing the top of the load within about 4-inches of the ground surface.

<u>NOTES:-</u>

Proposed Ditch Size		Suggested Loadings		Pounds Needed
Depth	Top Width	Distance Between Holes	Cartridges Per Hole	Per 100 Feet of Ditch
11/2-2 Ft.	4-5 Ft.	12”	1/2	25
21/2-3 Ft.	6 Ft.	15”	1	40
3-31/2 Ft.	8 Ft.	18”	2	67
4-41/2 Ft.	10 Ft.	21”	3	86
5-51/2 Ft.	13 Ft.	24”	4	100
6-61/2 Ft.	16 Ft.	24”	5	125

Fig. 126. “Single-Hole Column Loading Tables”.

Notes:-

The Post-Hole Method of Ditching

When you must blast ditches over 6-feet deep, the single-line column method is usually unsatisfactory because the small diameter holes just won't hold sufficiently large charges or provide a sufficient concentration of energy deep enough in the ground. Experience has shown that larger charges spaced at greater intervals will do a better job with greater economy. For such ditches we commonly use the **"Post-Hole"** method, also sometimes called the **"Single Row Deep Ditch"** method.

With this method we are able to routinely blast ditches up to about 12-feet deep and 36-feet wide at the top. Under especially favorable conditions ditches have been blasted 18-feet deep with this method!

We load much larger quantities of explosives than in the small diameter single-column loading method. And, we concentrate these explosives deeper in the ground. This permits spacing holes further apart, although this prevents us from using propagation firing when using the wider spacings.

The holes are usually made with a post-hole digger or large diameter earth auger. For the larger loadings, the holes may be "Sprung".

Charges are compacted at the bottom of the shotholes, rather than being strung in a column. The holes are normally dug to a depth of from one-half to two-thirds of the depth of the proposed ditch. In other words, if you want a ditch 12-feet deep, you would gig the holes from six to eight feet deep, the exact depth depending upon soil conditions.

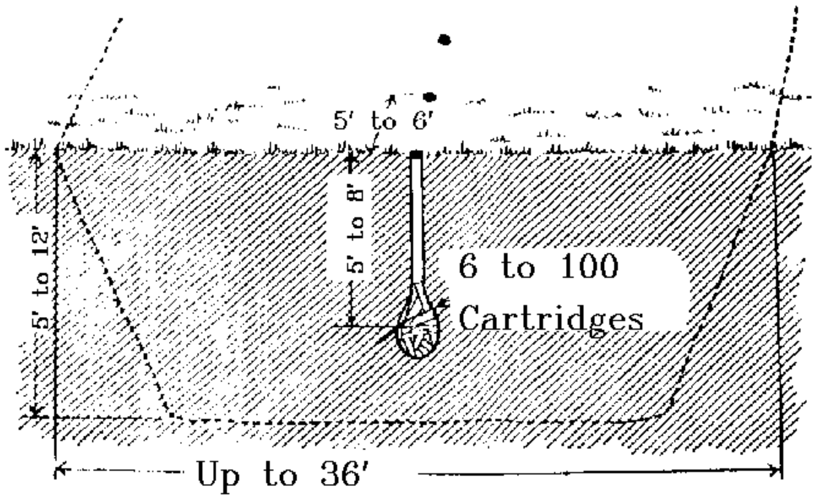


Fig. 127. "Post-Hole Method of Ditching".

<u>Notes:-</u>

The configuration of a ditch made by the post-hole method is illustrated below. The bottom width of the ditch is usually about the same measurement as the depth, and the top-width is about three times the depth.

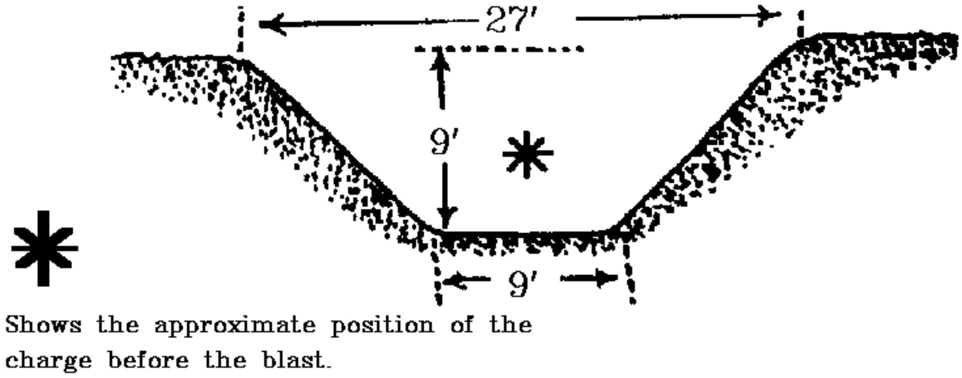


Fig. 128. "Configuration of a Ditch Made by the Post-Hole Method".

The propagation method may be used if moisture is adequate and the holes are at the closer spacings. However, electric methods are more common.

The Post-Hole method, in large loadings, is often more economical in terms of quantity of explosives needed than small diameter columns loaded. So while you might make your test-shot on the basis of **one pound per cubic yard,** you may be able to reduce this by as much as 20%. While this formula and these tables are quite accurate it is always a good idea to make a test-shot before loading a large number of holes.

If you are going to be doing a lot of post-hole loading, and will be ordering the explosives especially for the job, you can save yourself a lot of time and work by using large diameter cartridges, either 4 or 5 inch diameter ditching dynamite cartridges!

While the table which follows shows loadings for 4 and 5-foot ditches, with as few as 6 cartridges per hole, our experience is that fewer than 20 cartridges per hole **[10 pounds]** is not too satisfactory. Personally, we can't see much reason for using post-hole loadings for ditches less than 5 1/2 or 6-feet deep.

Notes:-

Below, we give specifications for post-hole ditch loadings.

Post-Hole Ditch Loadings

Proposed Ditch Size		Suggested Loadings					
Depth	Bottom Width Needed	Top Width	Diameter of Hole	Depth of Hole	Distance Between Holes	Cartridges Per Hole	Pounds Per 100 Feet of Ditch
4 Ft.	4 Ft	12 Ft	4 "	32"	3 Ft	6	100
5 Ft	5 Ft	15 Ft	4"	40"	3 1/2 Ft	10	142
6 Ft	6 Ft	18 Ft	6"	48"	4 Ft	20	250
7 Ft	7 Ft	21 Ft	6"	56"	4 1/2 Ft	30	333
8 1/2 Ft	8 1/2 Ft	25 1/2 Ft	8"	68"	5 Ft	50	500
12 Ft	12 Ft	36 Ft	8"	96"	6 Ft	100	833

Fig. 129. "Tables for Post-Hole Ditch Loadings".

NOTES:-

The Relief Method

If a large wide ditch is to be blasted, we sometimes use the **"Relief Method",** in which a small relief ditches are blasted on either side of the main ditch. This method is most often used when larger ditches are being blasted in heavy sod. A heavy sod is difficult to break, and a single row of charges beneath it may not efficiently throw the material because of the toughness and hinge-action of the sod. The relief method overcomes this by cutting and removing the sod along either side of the proposed ditch, before the main charge is fired.

If the ground is hard enough to hold a tractor, and if one is at hand, you can break the sod mat and often produce good results by simply plowing a single furrow through the sod on either side of the proposed ditch, before firing the ditch charge. Or, you can blast these ditches.

Relief ditches are always loaded by the single-column method. The quantity of explosives used in these relief-ditch charges has been described earlier.

There are two rules which must be followed in loading relief charges. One is that the wider the ditch is in relation to its depth, the greater the relief charge as compared with the center charge. The other is that the charges in each relief ditch must not exceed one-half the main ditch loadings!

It is not a good idea to load your main ditching charges until after the relief ditches have been shot! The ground movement may disrupt your main charges, causing cut-offs or throwing explosives about the area. So, load and fire your relief charges, and THEN load your main charge.

The main ditching loads may be loaded by the single-line column method as shown below, or by the post-hole method. Both have already been discussed and loadings given.

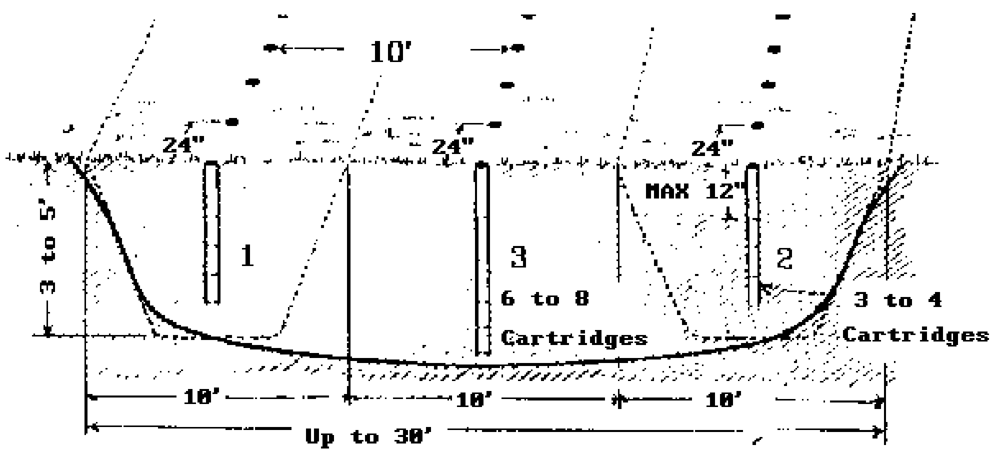


Fig. 130. "Main Ditch Loads, Loaded by the Single-Line Column Method".

<u>Notes:-</u>

Cross-Section Method of Blasting Ponds and Wide Ditches

We make the widest blasted ditches and ponds by the **"Cross-Section Method",** sometimes called the **"Cross-Row".** With this method we are able to regularly blast ponds and ditches to about 40-feet wide, and under favorable conditions up to 75 feet wide.

Cross-Section loading is most often used to make ponds for swimming, landscaping, irrigation, livestock watering, fish and water reservoirs.

If the ground is very dry or sandy, it may be more practical to dig ponds by machinery. However, many ponds are to be situated in a wet area, or areas which are wet during some part of the year, and blasting may be the fastest and most economical approach under such conditions.

Below we show the pattern of holes used in this method of loading. We make one row of closely-spaced holes running down the center of the proposed ditch or pond. Then, we make rows of holes running crossways. The center row of charges is usually loaded with twice the quantity of explosives as is loaded into the other holes.

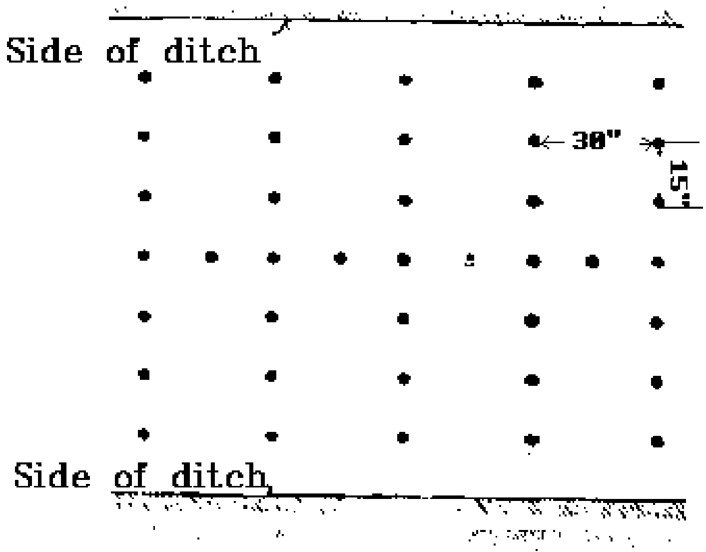


Fig. 131. "Hole Pattern for the Cross-Section Method of Blasting".

When these charges are exploded, the material is thrown into the air, and the center row of more powerful charges forces the whole mass of materials outwards, towards both sides of the pond.

One standard cartridge in each hole on the spacings shown will usually produce a pond from 2 to 2 1/2 feet deep. Two cartridges per hole should make a pond about 3 1/2 feet deep. Ditching dynamite is called for.

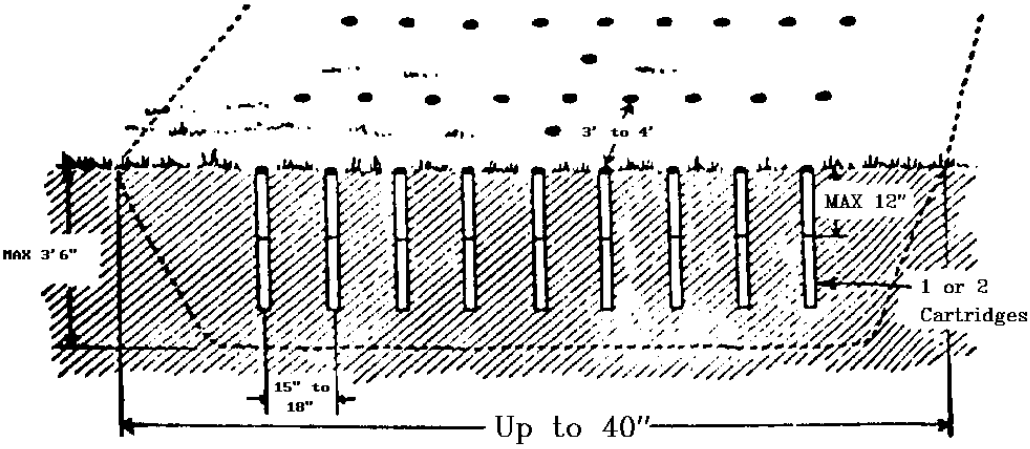


Fig. 132. "Cross-Section Method of Blasting Ponds and Ditches".

Sometimes, deeper ponds may be obtained by further increasing the number of cartridges per hole, although the method was designed to achieve width rather than depth. With heavier charges the distance between cross rows can be increased to a maximum of 60-inches, and the holes in the rows can be increased to 24-inch centers.

<u>Notes:-</u>

Cross-Section Loading Method

Cartridges Per Hole	1	2	3	4	5
Distance Between Holes	15”	18”	21”	24”	24”
Distance Between Rows	30”	36”	42”	48”	48”
Depth of Ditch	2 1/2 - 3”	3 - 3 /12”	4 - 4 /12”	5 - 5 1/2”	6 - 6 1/2”

No. of Holes Per Cross Row	Width	Dynamite Per 100’	Width	Dynamite Per 100’	Width	Dynamite Per 100’	Width	Dynamite Per 100’
3	11”	80 lb.	11’	133 lb.	13”	172 lb.	17’	200 lb.
5	11’	120 lb.	14’	200 lb.	17’	257 lb.	21’	300 lb.
7	16’	160 lb.	17’	267 lb.	20	343 lb.	25’	400 lb.
9	19’	200 lb.	21’	333 lb.	24’	429 lb.	29’	500 lb.
11	----	------	24’	400 lb.	27’	514 lb.	33’	600 LB

Fig. 133. “DuPont’s Recommended Cross-Section Loadings and Related Data”.

The ditch-blasting techniques discussed up to this point are often used for purposes other than constructing irrigation and drainage ditches. The same methods are also used for deepening or widening streams, and straightening or blasting new channels to control flooding. It is often desirable to alter the course of streams, to remove sharp bends, widen “Bottlenecks”, deepen shallow areas, and remove obstacles, in order to permit free run-off and reduce the chances of ice and log-jams and flooding.

Also, farmers sometimes use these ditching methods to quickly construct “Trench-Silos” and pits for burying refuse.

Notes:-

Pipeline Ditching

The ditching techniques we have discussed are also used on occasion to blast earth for pipelines. But mechanical digging is often better for such jobs, since such trenches must be refilled.

Pipeline blasting is usually done by larger, specialized contractors, because expensive rock-drilling, hauling, and re-filling equipment is usually required for economical operations.

When blasting ditches for pipelines and water, and sewer lines, the methods we have discussed are often unsatisfactory. One reason for this already mentioned is that such trenches must be refilled, and open-top blasting scatters the dirt leaving an expensive refilling operation. Also, such trenching must often be performed in built-up areas where large blasts and thrown material must be avoided. And, pipelines must be frequently laid through rock and other hard material seldom encountered in agricultural type ditching. Less important, because of refilling costs and right-of-way considerations, pipeline blasters usually want to blast as narrow and vertical-walled a trench as is possible.

Most pipeline contractors use mechanical digging equipment to remove soil and blast rock. Earth is usually removed by this digging equipment, until rock or other hard material is reached. Then, a small shot is fired to make a pit the approximate depth of the proposed trench. The broken material is removed. This provides an **"Open Face"** to work with, an open area into which blasted material can move.

Material is not thrown upwards, outwards, and away from the ditch as it is when open-ditch blasting. Instead, the trench is formed by a series of smaller shots breaking up the material, which is then removed mechanically and kept available for refilling.

Holes are usually drilled about one foot deeper than the depth of the proposed ditch. While one row of holes may be used for a very narrow ditch, most often two rows of staggered holes are used, as shown below. These are situated about one foot from the boundary lines of the trench, and will make ditches about 5 feet wide.

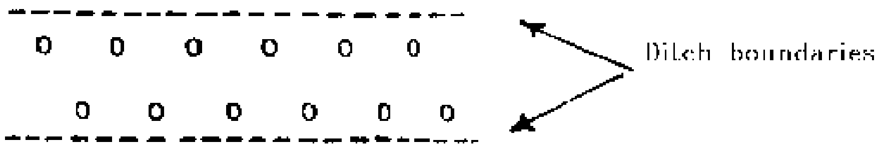


Fig. 134. "Staggered Pattern for a Wide Two Row Ditch".

For wider trenches, or in harder rock, one or more additional rows of holes may be added. And, in harder rock we place the holes closer to the boundary lines of the trench.

Each hole in a row is usually spaced from 30 to 48-inches apart, depending upon the drill-hole size and loading.

Author's Note:- On the Duke Point Pipeline south of Naniamo, BC, in the summer of 1981, we used a spacing the length of a long-handled shovel on all four sides, in the center of this pattern diagonally from the bottom left hole to the top right hole, we placed another hole. This gave us a five-hole pattern to allow us to place a 36" water line to the pulp mill at the other end. On that project, I worked as a driller on an Ingersol-Rand Air-Trac rock drill. We were drilling to a depth of 40 feet.

Best results are usually obtained when only one, two, or three holes are fired at a time, and the broken material is removed before the next blast.

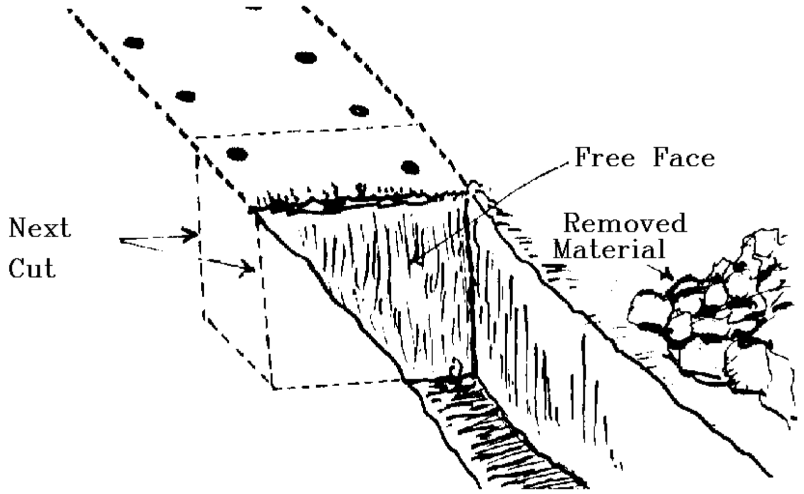


Fig. 135. "Broken Material Removed Before the Next Blast".

Both short and long-interval delay firing techniques are sometimes used to shoot longer sections of trench per shot. This improves the performance while still keeping ground vibrations low.

As previously indicated, it is important to maintain a free face which blasted material can move laterally. Following this procedure, trenches of 10 to 12 feet in depth can be blasted.

When deep trenches are needed, a procedure called **"Benching"** is often used. The final depth of the trench is reached in two or more steps. We blast down about half way, remove the rubble, and drill, load and fire again, moving down the trench in a step-like manner such as is illustrated below.

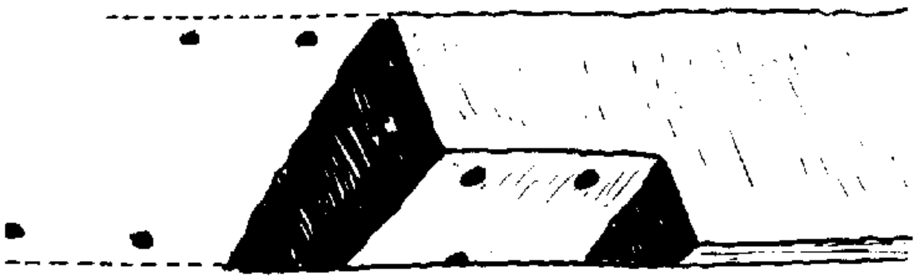


Fig. 136. "Step-Like Manner for Trenches".

In built-up areas, blasting mats must often be placed over each shot to eliminate flying materials. These can be woven-cable type blasting mats, or just a few logs or timbers chained together and lowered into place before each shot by a crane, loader or power shovel.

When working in hard clay, shale and other softer rock formations, a 40% extra dynamite is most often used. Special gelatin in 40% to 60% grades is more satisfactory in harder rock formations.

The quantity of explosives used varies with the nature of the material and the depth of the **"Burden"**, that is, how thick a section is being removed in one shot. As little as one pound per cubic yard is sometimes adequate. But, it can run as high as 4 - 5 pounds per cubic yard in very hard material and when **"Tight-Shooting",** that is, when the material being blasted doesn't have a **"Free Face"** toward which it can move.

Chapter XVI

Ice Blasting

In our most northerly climates, blasters, farmers, property owners and municipal and public safety employees are often called upon to blast ice. Ice jams may choke up streams and rivers, backing up water and causing flooding. And, ice may threaten to damage dams, bridges and other such structures.

Blasting ice is simple, however, we are frequently called upon to do so with a minimum of advance notice, on an emergency basis.

And since there is often little time for advance preparations, we will discuss the fastest and most simple method of blasting ice first. We merely place one or more fairly large charges of dynamite in bundles on the ice. If we can, we mudcap these charges or more often cover them with mounds of tightly-packed snow which we have wet down. If more than one charge is being used, it is preferable to fire all charges simultaneously. The accumulative shock effect will produce best results. Of course, this would call for the use of electric or detonating cord firing systems.

Typical surfaced-placed ice-breaking charges will each contain from ten to twenty pounds of explosives, with the exact amount depending upon the thickness and condition of the ice. If the ice is about three-feet thick, at least ten pounds should be used. On ice jams thirty to forty feet thick as much as 1,000 to 1,500 pounds of dynamite may be needed! The most common mistake is to under-load. With consideration to the emergency conditions usually existing, it is usually a good idea to load heavily, charges which you are certain will do the job.

After blasting deep ice, it may take up to 30 to 60 minutes for some fissures to form and all evidence of breakage to appear. Give it some time. Don't be in a hurry to get back on the ice if it doesn't appear to break up at once!

A more efficient method which may be used when time and conditions permit is to drill holes in the ice, tie explosives to a string which is in turn tied to a stick bridging the hole, allow the explosives to float under the ice, and fire, as illustrated below.

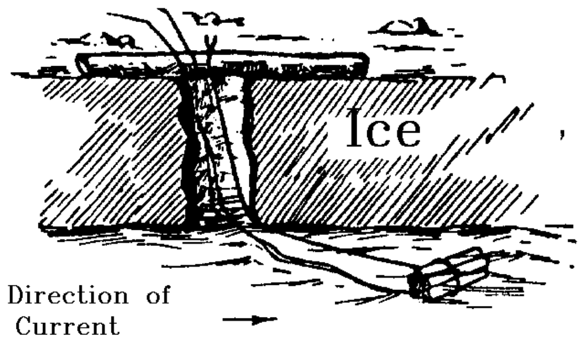


Fig. 137. "Drilled Holes With Explosives Under the Ice for Ice Blasting".

Ideally, the charge should be about two feet below the bottom surface of the ice, and not directly beneath the drilled hole. Such under-ice blasting is about eight times more efficient than surface blasting, and produces much less flying ice.

If a large surface area of ice is to be blasted, a series of holes are drilled and loaded as just described. If you are working with a sensitive explosive, and the holes are closely spaced, say not over five feet apart, they may all be detonated by propagation. Water transmits a propagating shock wave far more efficiently than air! But when firing by propagation, it is a good practice to prime more than one of the charges.

Any medium strength dynamite will do the job. Charges to be placed underwater should be of water resistant explosives and be waterproofed, although explosives with limited water resistance may be used if they are fired soon after being loaded. Again, we are considering the fact that we may be forced to use whatever explosives we have at hand, because of the time-element.

Understandably, you should attempt to place the charges with some consideration to the particular jam. Ideally, you would try to situated the charges at or near the key point which is causing the jam. The whole purpose is to blast so that following the explosion the ice-cakes created by the blast will be free to move off with the current.

Before blasting an ice-jam you should know what lies downstream. The on-rush of ice and water could do considerable damage to property such as boats, cottages, dams, and other structures, and may even endanger lives. In some cases, blasting may present more of a hazard than the jam, especially if it will result in a high wall of ice and water moving rapidly downstream into a built-up area!

In populated areas, the police should be contacted for advice and assistance with respect to warning residents. And underwater blasting kills fish and other submarine life, and should not be done except when necessary. Also, blasting in waterways is often prohibited by Federal Fisheries Laws, Provincial Conservation Laws, or other laws, and you may require special permission to blast.

T make a channel in ice, charges are placed one to two feet under the surface of the ice, in a row about four feet apart along the route of the desired channel. Place and fire simultaneously charges of about 2 1/2 pounds in each hole. This will produce a channel about three feet wide in ice up to about six-foot thick, under average conditions.

For a wider channel, place charges in two rows about five-feet apart.

Occasionally, blasters are called upon to free ice-bound ships. To do so, first select the point of maximum ice pressure on the ship, which may be indicated by some buckling ice. From this point, move out about ten feet from the hull, and dig a hole 2 - 3 feet deep in the ice. Place 2 - 5 pounds of a high velocity explosive such as a gelatin in this hole, and cover with tightly packed wetted snow or small ice fragments. When fired, the shot should relieve most of the ice-pressure and may free the ship.

Even when firing single independent shots, it is safer to use electric or detonating cord firing systems when ice-blasting, because the action is not initiated until you are safely ashore, unlike using safety fuse where you must light the fuse before starting off the ice. And, the components of electric and detonating cord systems are more waterproof than cap and fuse systems, which is especially important when using underwater charges.

The emergency conditions may, however, require the use of cap and fuse. In such an event, be sure to provide much extra fuse because of the possibility you may have a mishap on the ice and be delayed in reaching a place of safety. And, double crimp and waterproof the fuse-primer as best you can.

When working on ice, move about with extreme caution! Wear ice-creepers if they are available, and have a safety line attached and running to the shore, with assistance at hand!

It is a good idea to carry your loading-pole, even though it won’t be used for loading and tamping. It can be a lifesaver if you break through the ice! And, a trick practiced in the far north when working on ice is to wear woolen gloves or mittens. If you do end up in the water, the wet wool sticks well to the ice and provides a good hold for pulling yourself out!

As previously stated, don't be in a hurry to assume that an ice-breaking shot didn't do its job, and rush out to prepare another shot. Often the shot will cause cracks and breakage to form slowly, and there may be little or no evidence of break-up for several minutes. Then it could let go in a hurry!

And don't neglect adequate cover. Ice fragments make extremely dangerous missiles, if you are unprotected.

Notes:-

Chapter XVII

Blasting Steel

Blasting steel calls for the use of a very fast explosive, preferably one with a detonating velocity over 20,000 feet per second. And, since many techniques call for placing the explosive in intimate contact with the target, a cohesive and pliable product is best. A high velocity blasting gelatin in 80% strength is good. So are the military plastic explosives. Sheet explosive is excellent since it can be cut to any desired shape and size and formed around the target, with more than one thickness being used if necessary.

Most often, the steel you will be blasting will be of the structural type such as in **"I-Beams"**, steel plates used in building and bridge construction, and so forth. High-carbon or alloy steel such as used in certain shafts, machinery, and chain, is harder and more difficult to cut.

One of the most common steel-blasting jobs involves breaking up plates which have a riveted joint, such as boilers and ship hulls. In such cases, all that is usually necessary is to place a row of cartridges at the joint, as shown below.

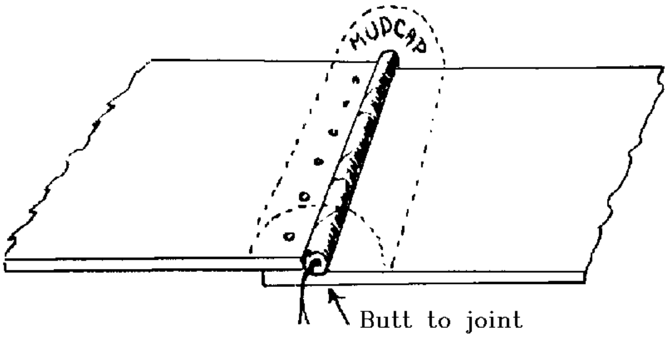


Fig. 138. "Cutting Steel Plate at a Riveted Joint".

Results are improved when the charge is mudcapped, and this is recommended whenever practical.

Notes:-

Below, we show the approximate weight of suitable explosives required for shearing steel plates.

Thickness of Steel In Inches	Pounds Per Foot to be Cut
1/4”	**1 1/2**
1/2”	**2**
3/4”	**2 1/2**
1”	**3 1/2**
1 1/4”	**4 1/2**
1 1/2”	**6**
1 3/4”	**7 1/2**
2”	**10**

In applying this table to structural steel members, you break the members down into their component parts. For example, an **“I-Beam”** is made up of a web and two flanges. A beam consisting of a 12-inch web, one inch thick, with two flanges six inches wide by one inch thick, referring back to the table . . .

3 1/2 Pounds will be required for the web;

1 3/4 Pounds for each of the two flanges. . .

Gives a total of 7 pounds of explosives to cut the member.

“H-Beams” are also made up of three plates, as are channel iron beams. A square box-beam is made up of four plates, angle iron of two plates, and so forth. In calculating the quantity of explosives needed, break such structural steel members down into the length and thickness of each of their components, calculate the charge needed for each, and total these.

Notes:-

When you have determined the quantity to be used, divide this in half and place one-half on each side of the target, slightly offset from each other. This is to create a **"Shearing Action",** and is illustrated below.

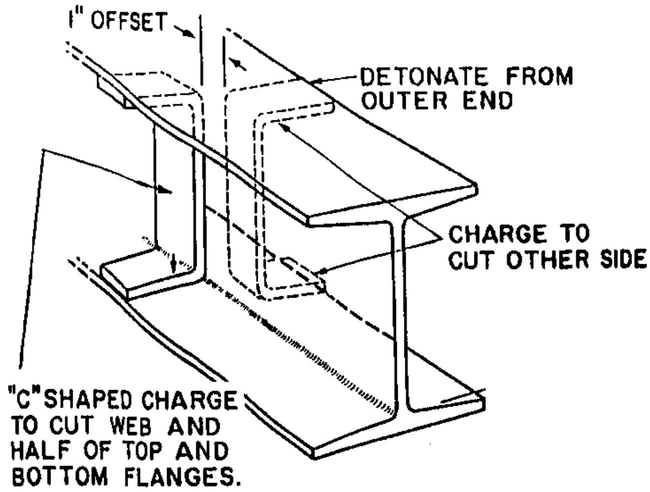


Fig. 140. "Cutting Steel With Explosives".

The amount of the offset should be approximately the same as the thickness of the material being cut, a little more being preferable to a little less. The **"Shearing Action"** produces better results than if the entire charge were placed on one side of the target. Of course, both charges must be detonated simultaneously.

Loading calculations may be kept to a minimum through the use of the previous loading table. However, there is a formula which you may use to determine the quantity of explosives required to cut structural steel. It is:

$$P = 3/8 \quad A.$$

Notes:-

Where **"P"** is the quantity of explosives, in pounds and **"A"** is the total area of the steel to be cut, in square inches. Application of this formula is shown below.

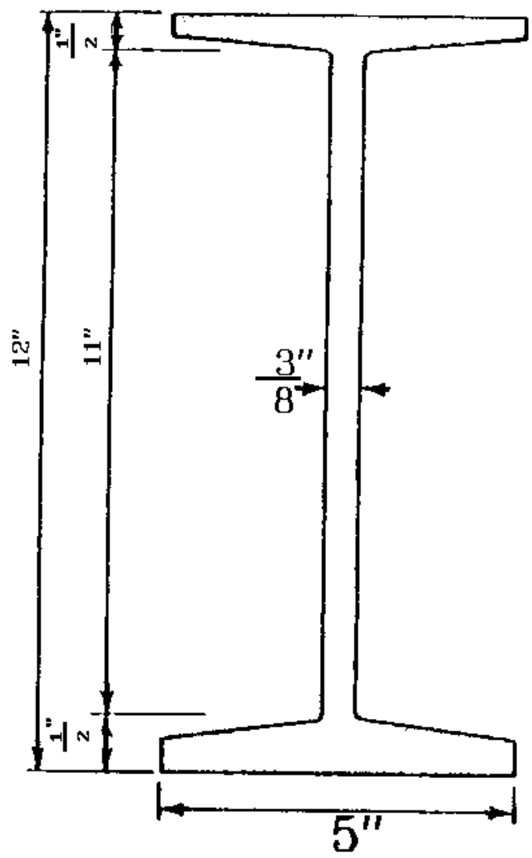


Fig. 141. "Charge Calculations".

P	**=**	**3/8"**	**A**		
			Area of Flange	**= 2 X 1/2" X 5"**	**= 5 Sq. In.**
			Area of Web	**= 3/8" X 11"**	**= 4 1/8 Sq. In.**
			Total Area	**= A**	**= 9 1/8 Sq. In.**

P = 3/8" A

P = 3/8" X 9 1/8" = 3 27/64

Use 3 1/2 Pounds.

Steel may also be cut through the use of either of two advanced charges, a **"Ribbon Charge",** or a **"Linear Cutting Charge".**

A **"Ribbon Charge"** is shaped to a thickness of three-quarters of the thickness of the plate plus one-eighth of an inch, and width of three times the thickness of the plate, as shown below. This will cut the plate at the center of the ribbon.

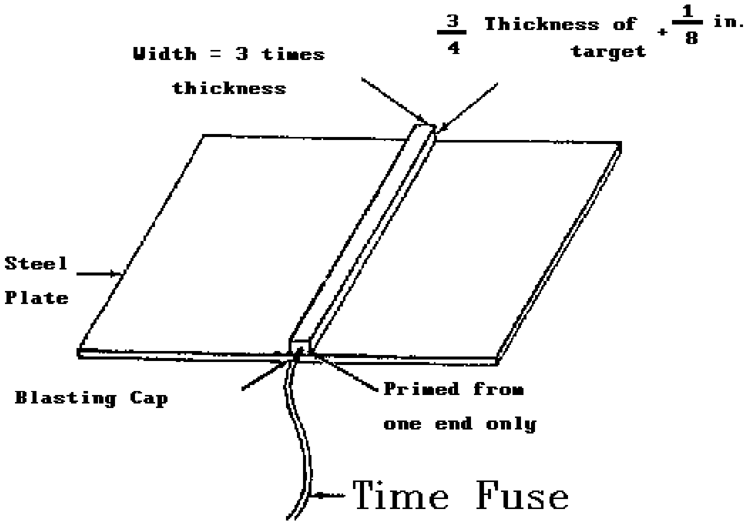


Fig. 142. "Ribbon Charge".

If the target calls for a relatively thin charge, the end to be primed can and should be built-up with additional explosives to better facilitate priming.

A frame for shaping, carrying and placing the ribbon charge can be made from stiff cardboard. In other words, it can be used as a template for forming the charge, as well as a means of conveying and placing it.

The **"Linear Cutting Charge"** relies upon the unusual action of charges known by various names including **"Shaped", "Munroe", "Directional", "Beehive"** and **"Hollow"** charges.

If two explosive surfaces are at an acute angle to each other and are simultaneously detonated, each will reinforce the other at the point of intersection. This forms a very high velocity jet capable of deep penetration into steel. In other words, much of the explosive energy is concentrated against one small area of the target, the shape of the charge causing a directional concentration of energy.

Below, we illustrate a simple cross-section view of a shaped cavity charge:

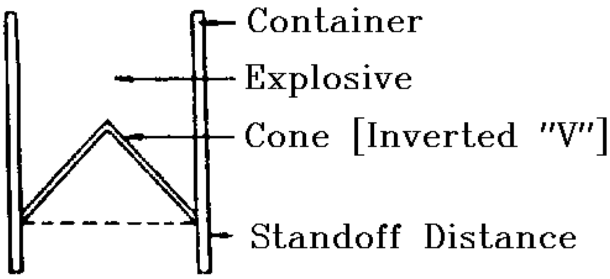


Fig. 143. "Cross-Section View of a Shaped Cavity Charge".

For maximum penetration cavity containers must be raised a precise height above the target, called the **"Standoff Distance".** This height is determined by the weight of the explosives and the size of the container, but it is usually 1 1/2 to 2 times the diameter of the charge.

Below, we illustrate a **"Linear Cutting Charge",** which is a shaped charge designed to make a long deep cut through steel objects. When such a charge is placed on top of an object such as a steel plate, it will create a long cutting jet capable of severing the plate.

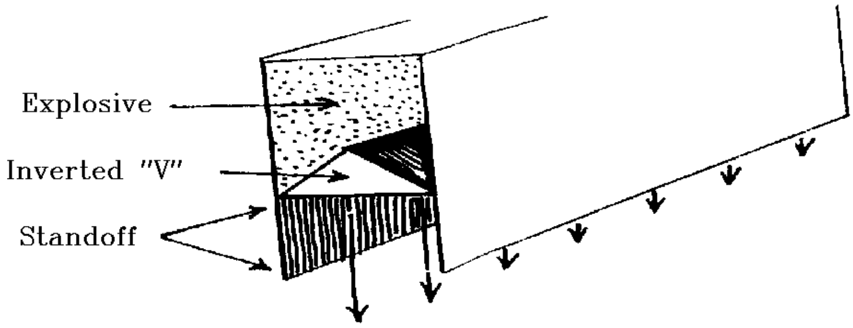


Fig. 144. "Linear Cutting Charge".

Linear Cutting Charges are manufactured for commercial use.

While on the subject of shaped charges, conical charges are sometimes used to punch holes into steel or reinforced concrete. These are difficult if not impossible to obtain commercially, and so we are presenting the plans for fabricating shaped charges yourself. In the first, a hollow-bottom wine bottle base serves as the container. In the second, the charge is made from a tin can and sheet metal.

NOTES:-

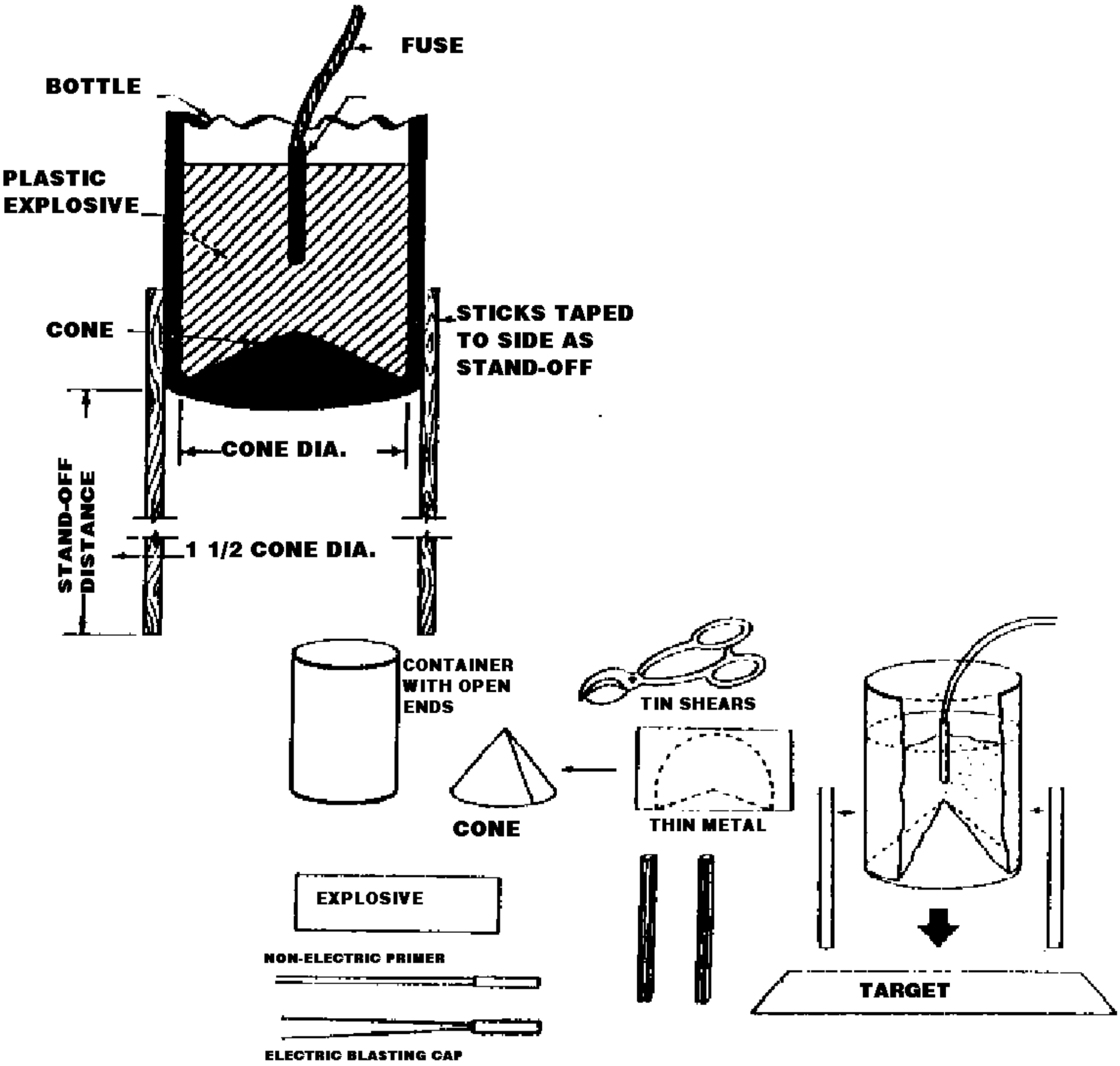


Fig. 145. "Plans for Fabricating Shaped Charges".

To give you some idea of the penetrating ability of shaped charges, US Military charges containing only 11 1/2 pounds of explosives are capable of making two-inch diameter holes 4 to 7 1/2-feet deep through 10-inches of concrete on top of 21-inches of rock, followed by compacted soil, through over 6-inches of armor plate, and through 7-feet of solid arctic ice!

The Military 30-pound shaped charge will penetrate 20-inches of armor plate, or 5-feet of the hardest reinforced concrete.

It is frequently necessary to shear steel rods, bars, shafts, chain, cables and so forth. To do so, load one pound for targets under one inch in diameter, 2 1/2 pounds for diameters of 1 1/2 inches, and 4 pounds for diameters up to two inches. The charge is divided into two parts, and half placed in an offset position on each side of the target. The amount of the offset used should be slightly more than the diameter of the target, and the charges must be detonated at the same instant.

A formula for calculating the quantity of explosives to cut such steel forms is:

$$\mathbf{P = D^2}$$

Where “P” is the quantity of explosives, in pounds, and “D” is the diameter of the target, in inches.

Applying this formula to cutting a two-inch bar:

$P = D^2 = P = 2 \text{ times } 2 = P = 4$ Load four pounds of explosives, two pounds on each side of the bar.

When working with small diameter members such as concrete reinforcing rod, proportionately more explosives must be used than when dealing with large targets, because their small size makes proper charge placement difficult if not impossible.

The formula **$P = D^2$** applies to targets under two inches in diameter. When the target is over two inches, the blaster reverts to the earlier formula, **P = 3/8 A**, where the area of the target must be calculated in addition to the diameter.

It is important not to under-load steel cutting charges. When your calculations result in an uneven figure, round it off to the next whole unit.

Two other advanced charges are used in cutting steel. The **“Saddle Charge”** is used to cut steel shafts up to about eight inches in diameter. It causes a **“Cross-Fracture”** in the target below the base of its triangular shape. The **“Diamond Charge”** is used on high carbon steel or hard steel alloy targets. It is shaped like a diamond and initiated at two points. The shock waves meet in the center of the charge and are deflected at right angles, cutting down into the target and severing it.

Since these charges must be shaped or cut, and formed around a target, only highly plastic or sheet explosives are suitable.

Working directly on the target may be difficult, so the blaster may transfer his/her charge dimensions to a piece of cardboard, and shape the charge on the cardboard template. Leaving the cardboard template on, place the charge on the target and tape or tie it in place. In attaching the charge, it is important that it is in direct contact with the target.

NOTES:-

Details respecting the **“Saddle Charge”** are shown below:

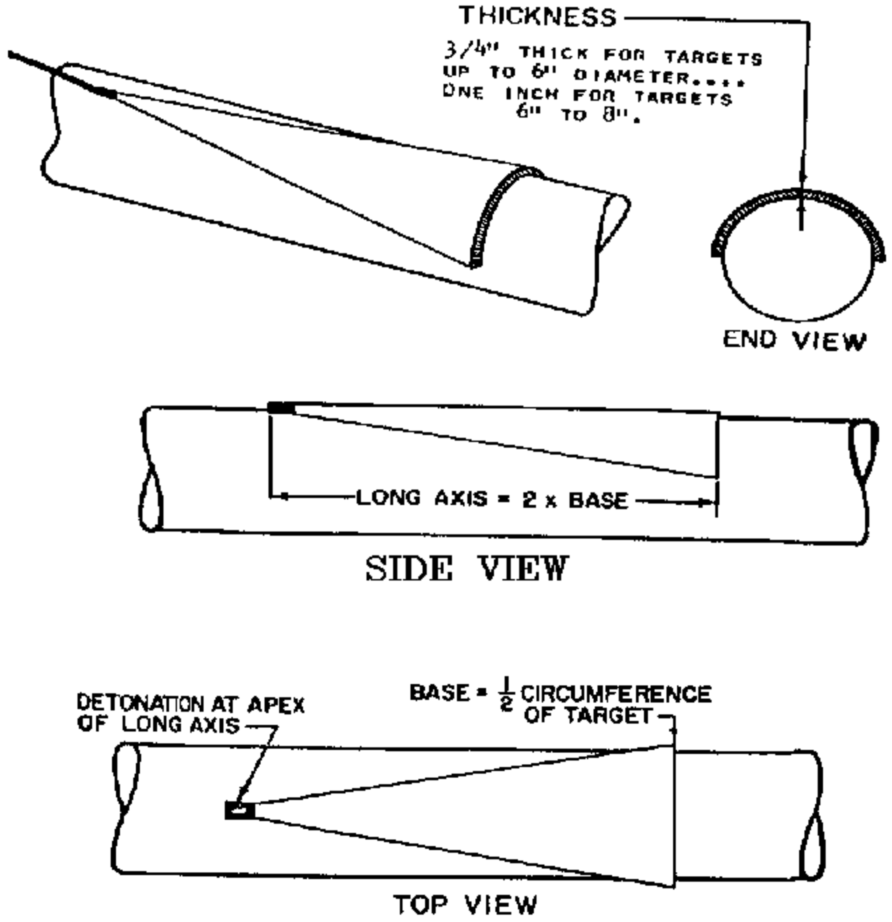


Fig. 146 . “Saddle Charge”.

Both the **“Saddle Charge”** and the **“Diamond Charge”** benefit from wrapping, such as covering the outside of the charge with heavy wrapping paper, aluminum foil, or the template material.

NOTES:-

The **“Diamond Charge”** and the manner of calculating its dimensions, are shown below:

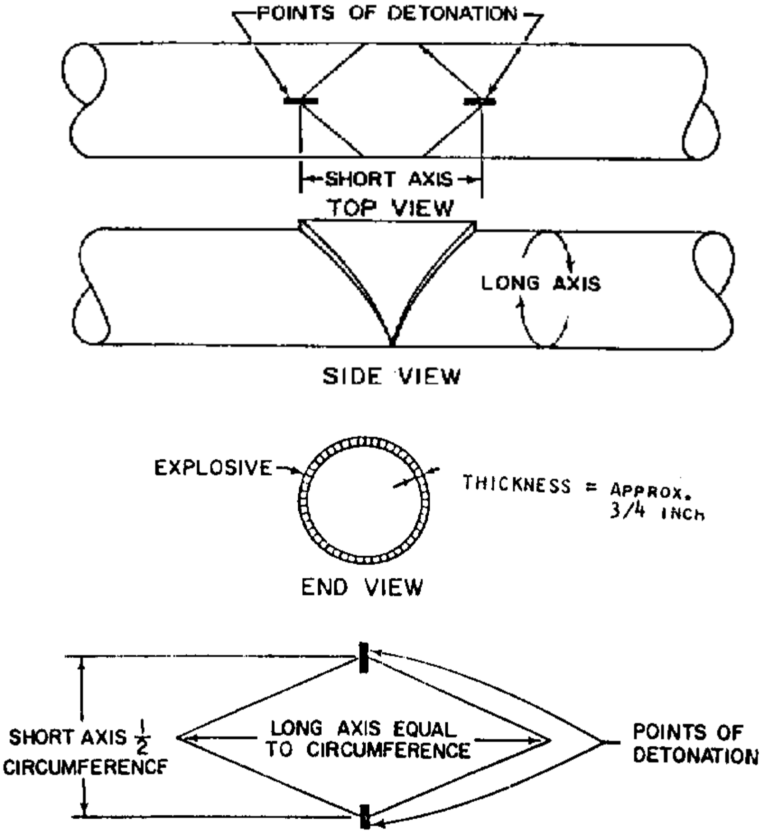


Fig. 147 . “Diamond Charge and the Manner of Calculating its Dimensions”.

The long axis is the same length as one-half the circumference of the target. The charge is three-quarter of an inch thick.

The US Navy reported using a Diamond Charge to successfully sever a destroyer propeller shaft seventeen inches in diameter!

Neither the **“Saddle”** nor the **“Diamond”** charge will produce reliable results against non-solid or hollow targets.

Another technique for breaking up old tanks, boilers, hollow-castings and the like is to fill the target with water and suspend single cartridges around the inside, about eight-inches from the edge. When these charges are fired simultaneously, shock-waves are carried through the water and burst the target.

When blasting metal there is a very real DANGER of flying fragments, and special precautions must be taken to protect persons and property. In many cases blasting mats or sandbags should be placed near the target in such a manner as to minimize flying missiles . Personnel should have a missile-proof shelter. When possible, personnel and shelter should be situated on the same side of the target as the charge, since most fragments fly from the side of a metal target opposite the charge.

Breaking and shearing steel with explosives is not usually difficult, and may be most practical in many situations.

BREAKING AND SHEARING STEEL WITH EXPLOSIVES IS NOT USUALLY DIFFICULT, AND MAY BE MOST PRACTICAL IN MANY SITUATIONS.

CHARGE CALCULATION

$P = D^2$

P = POUNDS OF TNT REQUIRED, AND

D = DIAMETER IN INCHES OF STEEL CHAIN TO BE CUT

DIAMETER = D = 1 INCH

$P = D^2$

$P = 1 \times 1 = 1$

P = 1 POUND OF TNT

USE 1 POUND OF TNT AT A AND 1 POUND OF TNT AT B TO DESTROY LINK

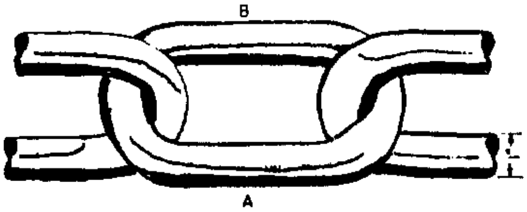


Fig. 148. "Cutting or Shearing Steel Chain with Explosives".

NOTES:-

Chapter XVIII

Underwater Blasting

Submarine blasting is performed in two ways, either working on the surface from barges, boats, or platforms, or by diving. We often see operations in which a combination of the two are used.

On many occasions individuals have indicated to the author that they were only interested in underwater blasting, and did not wish to bother learning any other aspect of explosives handling. This is foolish thinking, for numerous reasons!

First, whether explosives are being fired above or below water level they must be handled on dry-land, and this requires a general knowledge of explosives handling. Second, many of the operations connected with underwater blasts are actually pre-formed on the surface, such as making up charges and primers. And, the general techniques of using explosives underwater are most often identical to those used on the surface. For example, techniques of blasting a stump or cutting a timber underwater are basically the same as performing the work in a field.

Most importantly, the diver working with explosives faces special dangers due to his environment, and because of this should have an especially sound and complete understanding of explosives handling and usage.

Only expert divers should consider working with explosives underwater. Its not a job for a novice diver! He/She faces dangers on two fronts, his/her underwater environment which is hostile at best, and from the explosives he/she is working with. He/She must be sufficiently experienced diver that he/she can work underwater with little or NO conscious effort, and be able to concentrate much of his attention upon the blasting operation.

The diver working with explosives must often work under the poorest diving conditions. Visibility is often extremely poor due to the work and sediment which has been stirred up by previous blasts. He/She must often work at considerable depths, on bad bottoms and among many obstructions, where his/her attention is necessarily divided between his/her environment and his/her work. **In short, only a well-trained and highly experienced diver with a sound knowledge of explosives and blasting should ever undertake an underwater blasting job!**

Many larger underwater blasting jobs are actually performed from the surface, and this is considered to be preferable whenever practical. Jobs such as blasting bottom material from dredging, and deepening and widening channels for navigation, are most often performed on the surface, drilling and loading from barges or boats. The drills are surrounded by a casing or tube. When the proper depth has been reached the drill is withdrawn and the explosives are loaded into the shot-hole via the tube.

Or, sometimes explosives charges are merely lowered to the bottom by a rope and then fired. In blasting for pipelines crossing rivers, for example, very often a rope to which explosives have been tied along its length, is strung across the river and then lowered into position and fired. And, timbers and pilings are often cut off below the surface by lowering explosives tied to a rope or detonating cord loop.

When such jobs can be carried out from the surface, this is considered to be the safest method. However, there are obviously situations where the only possible or practical means of underwater blasting is through the use of a skilled diver. For example, projects such as removing underwater obstructions, removing or salvaging sunken ships, and small channel construction and maintenance jobs, are most often performed by divers.

It is obvious that explosives for underwater use should be water resistant. If a charge is to be in the water for only a few minutes before firing, then a product of medium water resistance will do. For longer periods of exposure, a product such as gelatin is best. Or blasting agents in waterproof containers are often used in larger underwater blasts.

It must be kept in mind that water is an efficient medium for transmitting blast-waves, much more so than air. Consequently, charges will be fired by propagation over much longer distances underwater, which may or may not be desirable in a particular blasting situation. When it is undesirable to have closely-spaced charges fired instantaneously by propagation, less sensitive explosives such as blasting agents in waterproof metal containers must be used.

It must be kept in mind that even a highly water-resistant explosive may be eroded by water, especially where the currents are strong. Accordingly, any charge which is to be left underwater for a considerable period of time subjected to water currents, should be protected from erosion by wrappings or coverings.

When carrying explosives on a ship or boat, high explosives and detonating cord should be carried on deck as far aft as possible. Preferably, they should be stored in an approved-type portable magazine or **"Day-Box".** If not, they should be securely lashed and protected by a waterproof and fire-resistant tarpaulin.

If the deck is steel, explosives should be placed upon a wooden platform or pallet.

All blasting caps and detonators should be carried on deck as far forward as possible, in their original cartons, in a watertight-wood-lined steel portable cap magazine, which should be well secured.

If small boats are involved, it is preferable to carry the explosives on one, and the caps on the another. Or if transporting the explosives to a destination where they will be unloaded such as a barge, it may be wise to make one trip with the explosives, and a second trip carrying the caps.

Obviously, explosives should be situated away from loading booms or hoists where they will not be exposed to falling objects. And, they should be isolated from potential sources of static-electricity, heat and radio frequency energy.

A boat carrying explosives should fly the **"BRAVO"** flag at the bow. However, since this is not likely to be understood by many boaters, **"EXPLOSIVES"** signs should be used in congested waters.

When diving in coastal waters, the **"Diver Down"** flag should be displayed. When diving offshore, either the international **"Underwater Task"** signal consisting of a red-ball, a white diamond, and another red-ball, should be hoisted six-feet apart, or the international code pennant **"FOX-TROT-CHARLIE-ZULU"** flown.

The diver is frequently called upon to blast out sunken logs and stumps. Charges are loaded in the same manner as on dry-land, as discussed in earlier chapters. Whenever possible, the charge is placed under the center and immediately against the target. If it is to be underwater for only a brief period, an explosive of medium water resistance such as an **"Extra"** dynamite in the 60% strength grades may be used. If it is to be exposed for a longer period, a 50% or 60% high velocity gelatin should be used. Firing should be accomplished with detonating cord, initiated at the surface by a fuse or electric blasting cap, preferably the latter. **Obviously, the diver should be out of the water and all persons removed to a safe distance before the charge is fired!**

In dealing with sunken logs which have settled into the bottom, several charges spaced at intervals may be needed to blast it out and break it up into sections.

Stemming is not required in such operations, since the water acts as a reasonably effective stemming.

Another blasting job commonly performed by divers is removing timber pilings. The techniques for doing this are identical to those described in an earlier chapter. The advantage of using a diver for cutting pilings rather than lowering the charge from the surface is that internal charges may be used in holes drilled by the diver, which greatly reduces the quantity of explosives needed to do a large job. Also, when dealing with piles which have been sunk in clusters or **"Dolphins",** the diver can blast each out separately, which is more economical than attempting to blast the entire cluster from the surface.

Again, detonating cord firing systems are best, initiated on the surface by a fuse or E.B. Cap. When detonating cord is used in underwater areas where it may be exposed to current or tide movement and come into contact with coral, barnacles, or sharp rocks, a heavily reinforced type should be selected, preferably wire-covered.

Divers are frequently called upon to explore, salvage, or remove sunken ships which are a menace to navigation. In many cases explosives offer the most effective means of performing such work.

It is not within the scope of this manual to discuss the diving considerations involved, such as the tide, wind, weather, wave height, characteristics of the bottom, age and location of the wreck, and so forth. The experienced diver must judge these conditions and the depth of the wreck, and select a time when the job can be performed with speed and safety.

The first step is a thorough examination of the wreck to learn its exact depth and how it lies on the bottom, whether or not it will be practical to safely enter the hull, and the best points to place the explosives to perform the task required.

Sometimes it is necessary to plant a few small charges around the hull to remove sand and mud and permit a more complete examination.

In some cases it will be necessary to blast holes in the hull large enough to permit the diver to enter, so he can work inside the hull. These entry holes can usually be blasted with between 25 and 200 pounds of explosives, depending upon the hull material and its thickness.

If the hull is merely to be blown apart or collapsed to remove a hazard to navigation, it may be necessary to blast through some of the main support members, in which case the reader should follow previous advise on steel-cutting.

Where it is only necessary to crush the hull downward to restore safe navigation depths, charges are placed directly upon the superstructure and decks, after protrusions such as masts, booms, funnels, etc., have been severed. Main support members may have been blasted beforehand. These charges are then fired simultaneously and one or more series will crush the ship downwards.

Sometimes cargo will prevent situating the charges inside the hull at the most advantageous places, and in such cases large holes are usually first blasted in the bow and stern, or through the sides of the hull if action of the current will be better from that direction, and further work delayed until the action of the water currents has cleared some of the cargo from the hold.

Generally, the best results in breaking up wrecks have been obtained by placing large charges spaced at closer intervals as far under the hull as possible, and directly against the bottom of the ship. More explosives are needed to do the job in this manner, and every effort should be made to place the explosives inside the hull.

It may be desired to salvage steel plates from the hull, and/or remove other structural members or fittings should be broken apart at riveted joints rather than by cutting through solid steel.

For small canal and levee deepening or widening jobs regular open-top ditching methods may be used if you are working with soft materials or cleaning out accumulated silt or sediment. Regular "Ditching Dynamite" may be used for such projects. Fortunately, many such canals have fairly strong currents which aid in the removal of the blasted silt.

Large harbor and channel deepening jobs are most often carried out from the surface, and undertaken by large specialized contractors because of the equipment which is required. This includes barges, boats, sophisticated drilling equipment, dredges to remove the blasted material, and equipment for hauling it away.

When shot-holes are drilled from the surface, these are usually 2 1/2 to 6 inches in diameter. A rule often followed is to drill these holes the same depth below grade as the spaces between holes. In other words, if you are spacing the holes on five-foot centers, they should be drilled to a depth of five feet. The maximum spacing is on 10-foot centers. A number of contractors specializing in submarine blasting all of their holes 10-feet deep, regardless of the depth of the cut to be made, and alter the borehole spacing and loadings to achieve the channel depth they want. The drills are usually encased in a heavy metal tubing which penetrates any silt, prevents loose material from falling into the drilled hole, and provides a means of loading the hole as the drill is withdrawn.

When relatively narrow channels are to be blasted, a column of explosives of about two-inch diameter may be tied to a rope and lowered into position. one or more such linear charges may be detonated simultaneously. Two to five lengths of two-inch diameter linear charges are most often used.

Another method of channel blasting with external charges is to place individual charges in three lines. The center line contains the heaviest loadings with charges spaced about three feet apart. Each outer line is about 10-feet from the centerline and charges are spaced 3 to 5-feet apart. A simultaneous blast of all charges should produce a channel through coral with gently sloping sides about 30-feet wide. The depth of the channel created will, of course, vary with numerous factors including the material, water depth, etc. Loadings can only be determined through test-firing.

Where the formation to be blasted is fairly soft, such as coral, limestone, or compacted sand, clay or silt, divers are sometimes used to place explosive charges of about 50-pounds on 8 to 10-foot square spacings on the bottom. Using 60% to 80% high velocity gelatin, and firing these external charges simultaneously, depths of three to four feet are realized. Dredging equipment is then used to remove the blasted material. The same technique is used when the bottom is hard material, but relatively thin and overlying a soft material.

Another method of deepening larger areas to a uniform depth, is to use a **“Checkerboard”** pattern with large charges spaced uniformly about 3 or 4 feet apart. Smaller charges are employed, and in some materials these lighter loadings on closer centers is superior.

The efficiency of these methods where external charges on a pattern are utilized depends, to some extent, upon the depth of the water. Since increased pressure tends to **“Confine”** the charge and direct more of the energy toward the target. Depths of over 25 feet are usually required before optimum results will be obtained from external charges.

For blasting channels in coral and other materials of similar hardness and strength, employing external charges, base your test-firings and approximate explosive needs on a power-factor of one pound per cubic foot of material to be removed.

When blasting channels in softer material, much less explosives are required. However, advantage should be taken of tides or other strong currents to carry off the suspended material. Little is accomplished if silt and other soft material settles back down into the channel! In fact it may not prove practical to blast shallow channels in loose materials such as silt. If the water is shallow and the channel fairly short, it is often more practical to move the material by running a large propeller boat held by an anchor-line, allowing the propeller-wash do the work, assisted by a strong tidal flow. Powerful water-pumps are also used to move light materials on the bottom.

It should be noted that if a line or lines of charges are to be situated in a strong current or tidal flow, the lines should be strung parallel to the water flow, if possible. If a line of charges are to be placed near a shore or surf, they should be strung perpendicular to the beach. Surf and currents do not move charges or strain detonating cord or rope and connections as much is lines run parallel to, rather than across the currents.

In Southern waters, it is often necessary to blast coral formations or **"Heads",** to make the area safe for navigation. It is not practical to drill boreholes in coral because coral particles clog a drill.

To blast coral with large external charges, a lower velocity explosive is best. Explosives such as ammonium nitrate in waterproof containers are the best to use in blasting coral and many other natural underwater formations.

Many coral heads are shaped like mushrooms, and the simplest method is to break the stem and let the head fall to the bottom. To do this, attach one suitable-sized charge against the stem, and one or more charges on top of the head. When detonated simultaneously, these should crumble the head.

When dealing with solid coral heads, place a number of charges on top of the head, to force it down, band a few charges down around the side or edges of the head and detonate all charges simultaneously.

Large loadings are required to blast coral with external charges, five pounds or more per cubic foot of coral blasted underwater. Blasting coral obstacles above water with external charges requires about three times as much explosives again.

Frequently, much time and effort goes into the preparation and placement of underwater charges, and a misfire could be costly, time-consuming and perhaps dangerous. When this is the case, especially when large charges or charges placed with great difficulty are involved, it is a good practice to minimize the chances of a misfire by using a dual-firing system. This can be done by looping the detonating cord trunk-line into a complete circle so as to provide more than one path for the detonating wave. Or, separate trunk-lines can be run, and double capped.

Underwater blasting is definitely not for either the novice diver, or the novice blaster!

The author, trained at Key West and Pensacola, Florida, with the **US Navy's, "Seal Teams"** in 1963, prior to spending three tours in-country in South Vietnam & six [6] months in a North Vietnam prison as a "Prisoner of War". I did not like their hospitality so I left their facility.

NOTES:-

Chapter XIX

Miscellaneous Blasting Projects

In this chapter we will consider numerous blasting jobs which are relatively simple and do not require much in the way of instruction.

By this time, the reader should have acquired a degree of understanding which makes it unnecessary to go into much detail. Once the fundamentals and principles of explosives usage have been understood and mastered, these can be applied to almost any type of blasting project.

Blasting Fence and Post Holes

Dynamite can be used very effectively in making holes for fence-posts and utility poles. Either to completely blast out the hole, or to merely loosen the material so it can be easily shoveled out.

To make a shallow hole in earth, such as you might want for fence-posts or shallow poles, you should first remove the sod and soft surface to a depth of about six inches, in a circle just slightly larger than the diameter of the hole you want.

Then using your driving-iron or punch-bar, punch a hole about the depth you want the post-hole to be. Load this with a small charge of from one-quarter to one cartridge of about 40% strength ammonia dynamite. The exact amount will depend upon such factors as the hardness and composition of the soil and its moisture content, and must be determined through experience or test-firing.

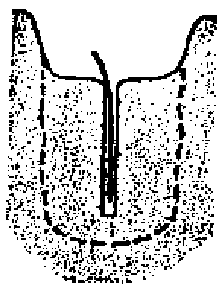


Fig. 149. “Post-Hole Blasting”.

The hole is then stemmed and fired, as illustrated, above. The blast creates the hole in two ways. First, it blows some of the material from the hole. And second, it forms the hole to some extent by compressing the surrounding soil.

The shot should pretty well form the hole and thoroughly loosen all hard material so it may easily be completed with the spoon.

When loading quantities of less than one cartridge, you will find that higher grades of dynamite are easier to cut into pieces without crumbling and more certain to fire. It is a good safety practice to use two caps when priming small charges.

For blasting deep holes in harder ground, we remove the sod as previously described and then punch a hole with a bar or auger. This hole should be a little DEEPER than the intended depth of the post-hole.

For our charge, we cut dynamite cartridges into pieces from 2 to 4-inches in length and tie or tape these to a stick or lath which will fit down into the hole. We space these small charges from four to six inches apart along the stick, and prime the uppermost piece.

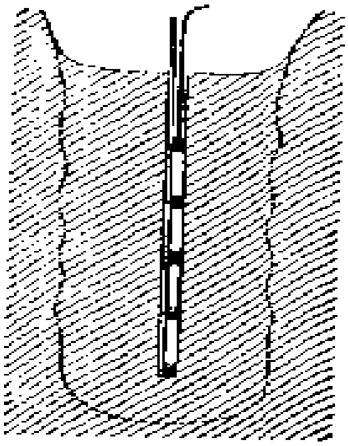


Fig. 150. "Post-Hole Blasting With Small Charges

The stick or lath is then lowered into the hole so that the primer is about 18 to 20-inches below the surface. Stemming is unnecessary and undesirable below the primer. However, if you are firing by cap and fuse you should put one or two handful of stemming on top of the primer to guard against explosives being ignited by a spark or flying match-head.

The primer will detonate the other small charges spaced along the stick by propagation if a reasonably sensitive dynamite is used. 40% to 60% extra or ditching dynamite are commonly used.

The blast forces back and compacts the sides of the hole, so that little or no shoveling is necessary.

In our judgment, an even better method of performing this job is to substitute a length of detonating cord for the stick. The pieces of dynamite may be taped to the detonating cord and lowered and fired in the manner just described. The use of the cord adds safety and convenience to the operation, especially if you are using a less-sensitive explosive spaced at greater distances.

Another method sometimes used in making large holes, is to lower a length of detonating cord the full depth of the shothole, and then add alternating layers of explosives and stemming.

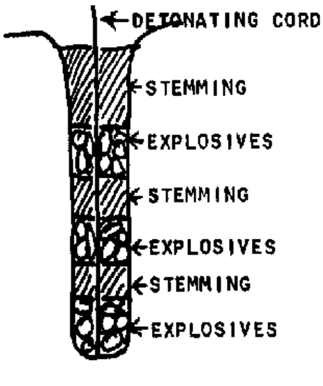


Fig. 151. "Alternating Layers of Explosives for Post-Hole Blasting".

When stemming is placed between explosives in the same column, the practice is called **“Decking”.**

The charges are more efficiently confined, while the propagation of all explosives is insured by the line of detonating cord. Making post or utility-pole holes in solid rock requires drilling. The practice is to clean away the loose dirt, and then drill a hole from 12 to 18-inches in depth.

This hole is loaded and stemmed. In average rock a 40% extra dynamite is recommended. If rock is very hard, a 60% strength will probably be better.

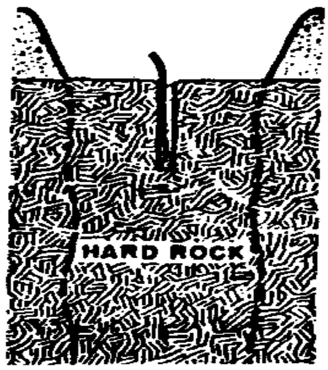


Fig. 152. “Blasting Post & Utility-Pole Holes in Solid Rock”.

The blast should shatter the rock to the full depth of the shothole. The burden rock is then removed and another hole drilled and loaded if additional depth is required.

This process is repeated as many times as necessary to obtain the desired depth.

Experienced shooters for utility contractors often lower the pole into position above the charge before firing it, which adds confinement, reduces fly-rock, and may improve the set of the pole.

In the North and swampy ground telephone and utility poles can be set this same way. Position the pole over the charge and fire the charge. The positive and negative forces of the blast will throw dirt to the side and the suction of the sudden explosion will pull the pole down into place.

Chapter XX

Tree Planting

Nursery personnel have a saying, **"If you are planting a $5.00 tree, dig a $10.00 Hole".** There is no finer way of preparing soil for tree planting than to blast the hole. This saves time and labor, but more important it thoroughly breaks-up and loosens the soil. When you blast holes for planting, the surrounding earth for some distance is broken, so that air can permeate it, rain water can soak in quickly and be stored, and stored water can be drawn when needed. Also, the thorough breaking of the soil makes it easier for roots to penetrate and become established.

Best results are obtained when the ground is dry. You should be able to pick up a handful of dirt and squeeze it, without it packing. If the soil is wet, the blast will likely pack the soil tighter, which is just what you are trying to avoid! If the earth breaks up loosely and does not pack, conditions are satisfactory.

Holes should be punched or dug about 3-feet deep, straight down exactly where the tree is to be planted. For small trees, this will be loaded with about one-half cartridge of a 20% to 40% extra or stumping dynamite. If shale or hardpan is encountered you would use a faster product and load more heavily. Also, if you are planting more mature trees with large root systems, heavier loadings may be needed.

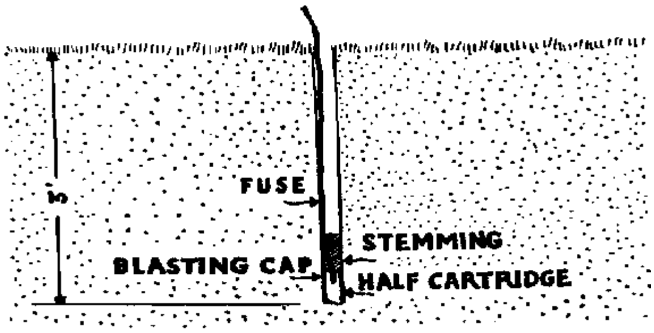


Fig. 153. "Tree Planting With Explosives".

NOTES:-

Chapter XXI

Subsoil Blasting

Much farmland which has been worked for many years tends to develop an artificial type of hard-pan just below the normal plowing depth, especially in heavy soils. This hard and often impervious layer is formed by the repeated packing of the underlying soil by cultivating and cropping.

This hard layer is detrimental to farming operations. Surface water cannot readily move downward through this layer, nor can ground water or plant food move upwards to nourish crops. It prevent rainfall from soaking deep into the earth and providing nature's reserve supply of ground-water. It increases the likelihood of both flooding and dehydrated crops and often hampers early spring operations because of water trapped on the surface.

Small amounts of dynamite, properly placed, will break openings in the hardened subsoil, thoroughly shake up and aerate the soil, and overcome many of the problems which come through long-continued cultivation.

Shotholes are punched in the soil in rows from 12 to 30 feet apart, with a punch-bar. Holes in each row are also spaced 12 to 30 feet apart. The spacings will depend upon the soil conditions, and should be determined through test-shots. The depth of each hole should be about 30 to 40-inches, depending upon the depth of the hardpan layer. Ideally, the charges should be placed to same depth as the layer, not above or below it.

Each shot-hole is loaded with one-half to one cartridge of an economical stumping explosive or low-strength ammonia dynamite such as 20% grade. Occasionally, in very tight soils the load may be increased, but usually one-half to one cartridge will do the job.

The holes are then stemmed and fired. About one quart of sand poured in the hole on top of the charge provides fast and adequate stemming. Tamping is not necessary or desirable.

It must be emphasized that just as in the case of tree-planting, subsoil blasting should only be performed when the ground is relatively dry. Blasting in wet ground may spring a cavity, and pack the soil rather than loosening it. The earth should be sufficiently dry that a handful may be squeezed without packing, remaining crumbly and powdery.

It is also best to do all subsoil blasting far enough in advance of speeding time to allow the soil immediately around the shot-holes time to settle.

Notes:-

The location of subsoil blasting charges is illustrated below:

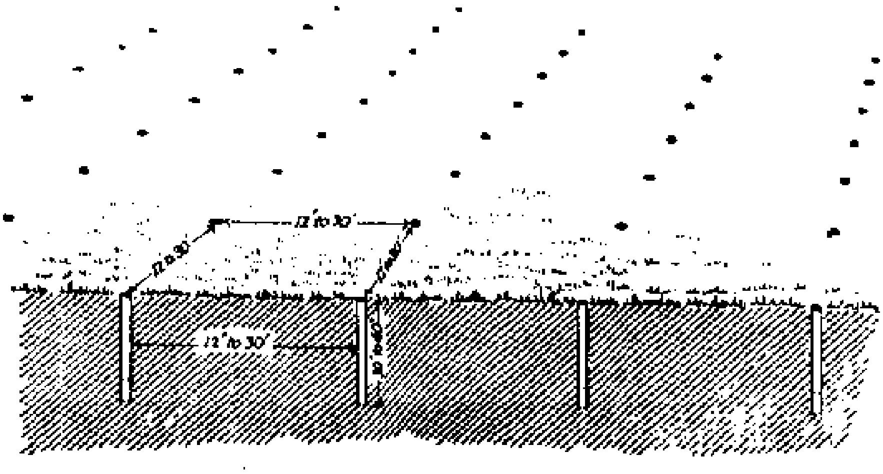


Fig. 154. "Location of Subsoil Blasting Charges".

The following table shows the number of holes per acre when subsoiling, depending upon the space of the holes.

Spacing in Feet	No. Holes per Acre
15 X 15	**194**
16 1/2 X 16 1/2	**160**
18 X 18	**134**
20 X 20	**109**
25 X 25	**70**
30 X 30	**48**
35 X 35	**36**
40 X 40	**27**

Fig. 155. "Subsoiling Tables".

From this table, the quantity of explosives per acre can be quickly determined.

To give the reader some idea of the economy of such an operation, if you were using half-cartridge loadings on 30-foot spacings. You could blast almost ten acres with one 50-pound case of explosives!

Chapter XXII

Building Small Roads

Small farm and property-development roadways can often be made with surprising economy with explosives. Frequently, blasting is the only practical method of constructing roads in rough country.

The object of such roads is primarily to permit the safe passage for the type of vehicle for which they are intended. Speed is seldom important, so the contours of the land can usually be followed, and sharp curves and rather steep inclines don't pose the same problems they would on a super-highway. Clearing the route and making it passable is the primary consideration.

Such things as trees and stumps, boulders, very steep grades, high rock crowns or ridges, and swampy areas are the type of obstructions most likely to be encountered. Of course, in laying out a proposed road reasonable effort should be made to by-pass extremely rough areas. However, most obstacles can usually be removed readily through blasting.

Boulders situated on the proposed route can be blasted by methods which have been previously described. You may not wish to completely remove the boulder from the right-of-way however, as this would leave a hole which would require filling. Accordingly, you may decide to use a faster explosive and heavy loading to thoroughly fragment it. Any excess could be removed, but much of the shattered rock would be left in the hole. Or, you may be able to simply shear-off the rock level with the grade.

Stumps and logs can be easily removed from the right-of-way by methods you learned earlier. In the case of standing trees, it is usually best to cut the tree with a saw, and then remove the stump by blasting. Again, you would attempt to avoid any large holes which would later require filling.

Areas where bedrock projects from the surface which would interfere with vehicle clearance, especially at the crown of the road or at the crest of hills, can be a problem. If not very high, these outcroppings can be most easily removed by mudcapping. If a considerable thickness is involved, it may be necessary to drill the shotholes and blockhole.

Occasionally, some excavating may be necessary, such as to reduce an impassably-steep grade. If you know you are going to have to excavate at some point, it is best if possible to do so in heavy earth rather than sand, gravel or rock. Open-top ditching methods may then be used.

If you will require rock fill for a low-lying or soft area along the right-of-way, you may blast rock for this purpose. Either in cutting an excavation, or from a nearby rock ledge or face. Ideally, surplus material from high areas should be used for filling-in low areas. In laying-out the proposed right-of-way consider such **"Balancing".**

There are two types of right-of-way cuts or excavating. These are **"Through Cuts",** where the excavation is made through a hill. And, there are **"Side-Hill Cuts",** where an excavation is made along the side of a hill. Side-hill cuts are the easiest and require the least explosives, because you are working with a natural free face. Also, a relatively small side-hill cut will often provide a fairly wide roadway surface because the material being removed from one area is used in extending the road width. If some or all of the fill is not needed, it may be **"Wasted",** blown off the right-of-way. If more is needed, it may be **"Borrowed"** for a nearby area. When working with explosives, you can create your own fill as you need it!

If the road must cross a swampy area, some filling would likely be required. You should probe every few feet along the proposed road to determine how much soft material is on top of a solid base. If it is just a foot or two in depth then heavy rock fill will displace the soft material and provide a good roadbed.

If the muck is deeper, it may be removed and a solid surface obtained in any one of three different manners. If the muck is not more than 6 - 10 feet deep, you can blast a right-of-way through it using previously described **"Open-Top Ditching"** methods. Loading so as to get down to the solid base. If the material is very wet it may move back into the cleared area rather quickly, so fill should be ready for placing into the blasted section as quickly as possible.

Another method of fill settlement is called **"Toe Shooting".** This is common in large road-building projects. It consists of shooting the muck just ahead of the advancing fill. Before the blast, the fill is piled into a **"V",** with the point of the **"V"** in the direction the road is being advanced. Charges are loaded into the muck below the bottom of the fill, along each side of the **"V"** and just in front of each side of the **"V".** When these charges are fired, the muck is displaced and the fill settles to the solid bottom underneath. The charges should be spaced about ten feet apart, and loaded to the ratio of two pounds of explosives for each foot of muck depth per hole.

And the third method is called **"Underfilling".** The necessary depth of fill is placed directly on top of the muck. Then, explosives are loaded into holes or casings driven directly through the fill and well down into the muck. When these charges are exploded, the blast liquefies the muck and drives it out sideways from under the fill, permitting the fill to settle into place. In using this method the muck should be four to ten feet deep, the fill must be heavy, and the holes not overcharged. Otherwise, the fill might be scattered by the blast.

While we have discussed putting a right-of-way through wet or low-laying areas by blasting, the reader will recognize that there are circumstances under which it may be easier to build a small bridge, lay a culvert, or make a short stretch of log or **"Corduroy"** road.

Blasting a farm or access road is not usually very difficult, and can often be done by explosives at a fraction of the cost of having it built with heavy equipment. Many different types of blasting may be involved, and this is an ideal type of project for the person wishing to gain experience in numerous types of blasting in one job or project.

NOTES:-

Chapter XXIII

Excavating

Explosives often provide a highly economical and efficient means of excavating. Under some circumstances, the material to be removed may be blasted from the site by explosives alone. In other cases, explosives are used to loosen or break-up the material, which is then removed mechanically or by hand.

If an excavation is to be made in soil or softer material, ditch and pond-blasting techniques or loadings may be used, providing the larger single shot and flying material would not pose a problem. You will recall, however, that these methods produce excavations with sloping rather than vertical walls, as shown below.

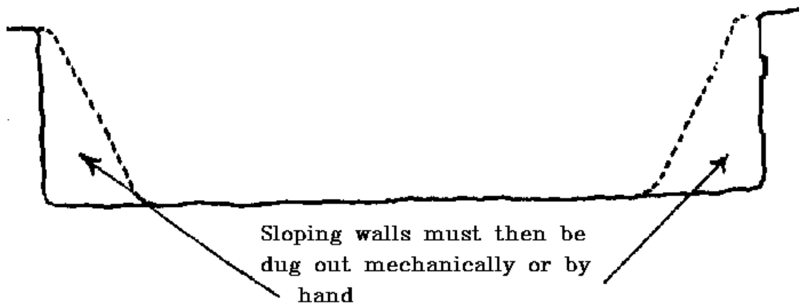


Fig. 156. "Using Explosives for Excavating".

Accordingly, it is necessary to position your charges so the top, or widest part of the ditch, will be a little inside the final excavation line. It will then be necessary to dig out the sloping walls to produce a vertical-walled excavation.

When excavating for cellars and foundations, care should be taken to avoid situating the charges too close to the side walls. If the dirt there is loosened or otherwise disturbed, it may not provide the support which will be required of it, or may even collapse. Keep this in mind when positioning your outer rows of charges. It is better to have a little digging to do, than to attempt to blast out all material and have a collapsing wall!

Other excavation techniques are generally designed to break up or loosen the material to be excavated, which is then mechanically removed. This is essential when attempting to excavate in rock and shale, and saves much time and labor when excavating in hard-packed earth or clay.

Instead of blasting an excavation in one step, we do so through a series of steps and shots. Generally, we first make a hole or ditch along one side of the proposed excavation. This is to provide a **"Free-Face"** or opening into which blasted material can move. This preliminary excavation should be the same depth as the proposed excavation. Then, we place a row of shot-holes parallel to this, and fire these. This breaks up the soil and moves it into the preliminary excavation. It is then removed, and another row of holes loaded and fired. This is done until the excavation is the size required.

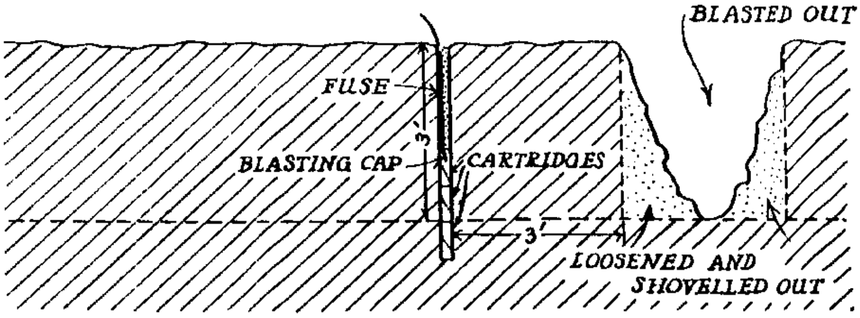


Fig. 157. "Excavating Blasting with Explosives".

Note that the shot-holes are made a little deeper than the proposed depth of the excavation! This is very important. Also, care should be taken to make all holes the same depth, in order to produce an excavation with a level bottom.

Each row of charges should throw a considerable amount of material from the excavation. The remainder will be broken up to a degree whereby it can be easily removed.

For heavy clay, soil, shale, and hardpan, a medium strength dynamite such as a 40% is usually suitable. Charges should be well tamped and fully stemmed.

Loadings will vary with the nature of the material, as will shot-hole spacings. However, to produce an excavation six feet deep in the average clay soil, holes would be spaced about four feet apart in a row, and each row back approximately four feet from the previously blasted area. Three cartridges in each hole should do the job. The holes should be about 6' 6" to 7 feet deep.

It is important that any material which is not blasted out of the excavation be removed before firing the next row of charges, in order to maintain a free-face into which blasted material can move. Much higher quantities of explosives are needed, and poorer results obtained, if this is not done.

If boulders or rock-ledges are encountered while blasting an excavation, these may be broken-up by methods described elsewhere in this manual.

When blasting excavations for cellars and foundations in hard rock on level terrain, we most often use the technique of making one first cut in the form of a hole in the center, and progressively work outward from this with rows of drillholes circling the original cut. We frequently use delayed firing techniques, but less explosives are needed if we shoot one row of charges at a time and remove the blasted material before shooting the next row.

When working in rock, a faster explosive and one with a higher loading density is better. A special gelatin in 40% to 60% strength grades are a good choice.

Care must be taken to prevent **"Overbreak",** that is fracturing the rock beyond the next excavation line, and this must be considered in laying out the drillhole pattern and loadings.

And, when excavating in close proximity to a building, roadway, etc., it may be necessary to eliminate any fly-rock by using blasting mats, to timbers chained together, which are lowered on top of the charges before firing.

Generally speaking, excavating in softer materials with explosives is not difficult or highly technical, and can save much labor and time. Excavating in rock is a little more difficult, and requires drilling equipment. Excavating large areas to considerable depths, such as is seen in advancing highway right-of-ways, requires elaborate drilling and hauling equipment, and is beyond the scope of this manual.

Notes:-

Chapter XXIV

Demolition's

There is a tendency to regard "Demolition's" as a highly specialized form of blasting. Although there are blasters and contractors who specialize in this type of work, and special engineering skills are required on larger projects, the demolition of structures by explosives is largely a matter of applying relatively simple blasting skills.

When an individual sees a building being demolished by what appears to him/her to be a single blast, he/she considers the operation highly technical. It may be from an engineering viewpoint, but it seldom is insofar as the blasting itself is concerned.

Actually, building demolition generally consists of nothing more than destroying the key structural members of a building in such a manner that the building will collapse of its own weight. The reader likely has an adequate understanding of explosives usage to handle the blasting aspects. **Whether or not he/she has an adequate understanding of building construction and architectural engineering to identify the vital structural members to destroy is another matter!**

The destruction of a structure does not occur as a result of one large charge, but rather it is the result of a number of small charges usually fired simultaneously, which destroy the supports holding the building up. The target, therefore, is not the structure itself, but the key members which are supporting it. **The object is not to blow the building Up, but rather to destroy its structural integrity so it will collapse.**

Key structural members, whether vertical or horizontal, will usually be made of steel, timber, brick or block or reinforced concrete. Earlier chapters have described how to determine the size and placement of several kinds of steel and timber-cutting charges. A table showing charges for breaching concrete and reinforced concrete members appears below.

THICKNESS OF CONCRETE IN FEET	REINFORCED CONCRETE				(DENSE) UNREINFORCED CONCRETE			
		(TAMPED)		(TAMPED)		(TAMPED)		(TAMPED)
1	5	5	5	5	3	3	3	3
2	22	8	28	16	14	5	18	10
3	52	21	67	41	40	15	51	29
4	124	49	159	88	86	34	110	61
5	219	79	282	157	145	52	186	104
6	378	135	486	270	250	89	321	179
7	517	185	663	369	337	120	433	241
8	771	276	991	551	502	170	646	359
9	1098	392	1411	784	715	255	919	511
10	1505	540	1935	1075	980	350	1260	700

NOTE: At least 5 lbs. for reinforced concrete.
At least 3 lbs. for dense concrete.

Fig. 157. "Table of Charges for Breaching Concrete & Reinforced Concrete Members".

In determining the size of charges to be used, keep in mind that it is seldom necessary to employ charges which are sufficiently large to completely sever all targets. **Since targets are load-bearing members, it**

is usually better to use "Pressure Charges" which will damage the vital members that they will collapse because of the weight they are supporting. This requires less explosives and poses fewer blast-related problems.

Let's face it, any idiot could destroy any structure given enough explosives!

The blasters expertise lies in his/her ability to do so with an absolute minimum of explosives and blast problems such as ground vibrations, blast, etc.

Steel-framed buildings may be demolished by simply blasting the vital steel members. If these are encased in concrete or masonry, it will be necessary to first blast the away in order to expose the steel beams.

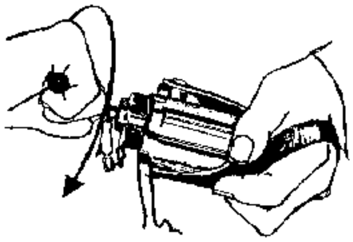
Smaller wood or thin-walled buildings may be demolished by closing all doors and windows, or better still boarding these up, and firing a concentrated charge on the ground floor. Charges of from one-quarter to one-pound of explosive per cubic yard of volume will totally destroy such buildings.

A practice preferred by this author is to suspend a smaller charge in the approximate center of the building. When this is fired it will often thoroughly loosen all the materials in the building so they can be much more easily removed manually than would have been the case otherwise, and few of the materials are destroyed.

Smaller masonry or concrete buildings may be destroyed by **"Breaching Charges"** placed on the inside and on the base of exterior walls at key points.

Large industrial concrete beam curtain wall buildings constructed in such a way that the load is carried by reinforced concrete beams and columns, may be demolished by placing breaching charges inside the building at the base of the exterior wall and at the base of all intermediate columns on the ground floor.

A high velocity explosive comparable with 60% nitroglycerin dynamite or a fast gelatin, is usually best. All charges should be confined and tamped, if possible.



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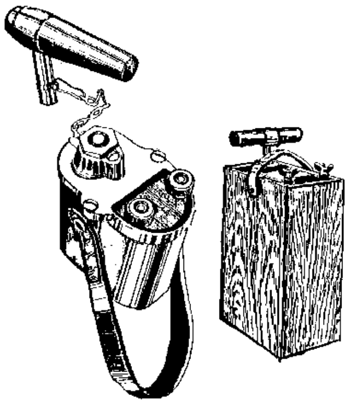

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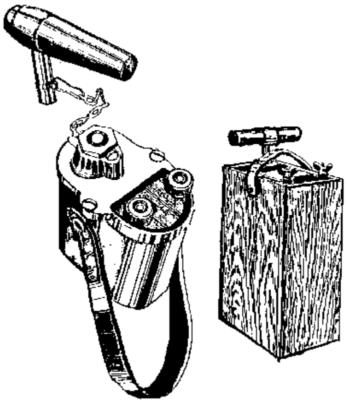

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