The Use of Explosives

for

Agricultural and Other Purposes

Published by
The Institute of Makers of Explosives
103 Park Avenue, New York City
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How weeds and briars grow up about a boulder in a field. In this case the stone itself is not very large, but the total land area put out of business is three times as much as the stone covers.

INTRODUCTORY

THIS bulletin is published by the Institute of Makers of Explosives. The aim is to give the united conclusions and the sum of the experience to date of nearly all makers of explosives and of farmers who have dealt successfully with the problem of the uses of explosives on the farm.

The material has been classified and assembled so any phase of it will be available easily and quickly. Uncertainties have been eliminated as much as possible in favor of known facts and formulas established by actual experience. It is offered as a manual or handbook for farmers, home and road builders, contractors, park makers and others who must remove rocks and stumps from land, and as a textbook for students of agriculture.

Readers will find that the recommendations are impartial, and that the suggestions on that part of the work which can be done best with explosives are particularly complete.
Boulders and Ledges of Rock

Eight generations of farmers have picked stones off the fields of a great many farms in this country, and in these same fields all the boulders too big to be moved by the direct strength of men and horses still are dodged by the present farmers. Some land cleared and farmed as long ago as the Revolutionary War has not had the “niggerheads” removed to this day.

Those stones that project above the surface of the ground can be avoided, but those hidden underneath are more serious trouble makers. The man who works his own land for years gets to know where they lie, and can escape them to a certain extent, but it is by broken plowshares that a new plowman learns their location.

In former years, before the value of land began to increase as it has of late years, farmers found more profit in locating a new acre that had fewer stones or none at all than in removing those from a stony acre. But that time is past. Farm land today can be made to pay without removing the boulders, but a far greater return can be had if they are removed. Stony farms can be sold, but not for big prices. Thoughtful farmers remove the rocks.

It is surprising how much there is to know about the disposal of boulders. Too often this work has been attempted in ways that were crude and wasteful of energy and time, and considering these items, very expensive. This is partly due to the lack of published data describing easier, simpler ways. The up-to-date farmer will not tolerate methods that are wasteful or unprofitable. He may find the information he wants in the following pages.

The Profit and Loss Account of Boulders

The interference of boulders and rock ledges with farming operations and profits takes many forms, and its cost can be estimated from a glance at a few of them.

This is the sort of perpetual tenant which pays no rent, and on which this bulletin declares war.
On ground where a cultivated crop is grown, each boulder causes the waste and loss of about half an hour per year of the time of a man with a team, worth five dollars a day. Four seasons’ loss will remove the Time Lost stones. They “eat their heads off” as the saying goes, ten or more times during the active lifetime of the average generation.

In addition, the breakage and damage to tools and machines may amount to as much in total loss as that from waste of time. This is particularly true of those farms where modern heavy implements are used, as, for instance, the heavy disc harrows for four or more horses, the gang plows, and all the tillage tools pulled by traction engines. Tractor plows and harrows are sure to be broken in stumpy or rocky land. It is impossible to make good time with gang plows or harrows among boulders, because of the constant stopping necessary, and besides, the work done is bound to be poor. Ten to twenty boulders to the acre are just about as bad as 100 for the man with the engine implements—they make good work and speedy work impossible.

About each rock that sticks above the surface some weeds are sure to grow. There never is the stone, or log, or stump, on or in the ground but where you can find a thistle or two, or several specimens of other equally noxious plants, growing close to the edge or out from under it. These single weeds re-seed entire fields.

Another feature of the loss sometimes caused by tight stones in fields is the injury to horses and men caused by the sudden strain and jerks. Horses sprain leg joints, shoulders, hips and backs. Many spavins have their beginning in the ugly twists sustained. Brood mares often are caused to lose their foals prematurely. The baffling for which stones are responsible is one of the most common causes of balkiness of farm horses. A team can be ruined in a short time by such treatment.

The danger to men is not so common, but when it does come it comes heavily. The records of the past generation show that many a farmer was struck with a plow handle when the plow point encountered a stone that was tight. Sometimes the result is a broken arm or hip, or rib, or worse still, a rupture. The newspapers frequently report accidents caused by the driver of a mowing machine being thrown from the seat into the knives, or under the heels of the horses, when the machine suddenly struck tight obstructions such as stones.

The direct loss of crops which would grow on the land occupied by the boulders need not be stated in figures. Every farmer knows that the loss of corn, wheat, or hay on a square rod amounts to 15 to 50 cents a year.

Tight stones on a farm are bound to keep its selling value down. One of the first things a shrewd buyer of land will want to know is whether the soil is free of rocks that interfere with cultivation. One of the easiest and surest ways of increasing the value of land, for selling, for actual use, and in the estimation of other people, is to clear away the boulders.

The stones themselves may not be without value when they are broken up in pieces small enough to handle. It is well for every farm to have a pile in some convenient place, where they can be had any time they are wanted. They are valuable for building material, and in drains and walks. At the rates prevailing in many places it is easy to collect fifty dollars’ worth of stone right
near where it is needed and save both the cost of the stone and most of the expense of hauling.

Some of the more common purposes for which stones are valuable on farms are for blind drains, for lining ditches along roads or in fields, where the water gouges out the sides or bottom on account of a grade or turn, for road foundations, for repairs to walks, for constructing steps, chimneys, walls, etc., for filling in concrete construction, and for building garages, houses, barns and silos.

Clearing land of boulders should not be regarded as an expense, like taxes, or like the cost of shoes to wear. It is an investment, like the purchase of Government bonds, or like the purchase of shoes by a storekeeper, to sell again. When money is spent for removing boulders by a farmer, he is buying something—the clean land—that at once begins to pay back the cost of the work. It pays for itself within three or four years and then keeps right on paying dividends year after year.
Kinds of Rock and Their Nature

It helps if you know your rock when you go to break it up, for many different kinds exist as boulders and ledges on farms and in roads. In some sections the term "hardhead" is used to describe one kind of boulder. Another term is "niggerhead." It is better to know the rocks by the names which designate their real nature.

Rock Qualities

What does make a difference is that some stones are easy to break and others are not. To understand why, a study of the stones is necessary. Their resistance depends on their comparative hardness and toughness. These two qualities must not be confused, for they are not the same.

Hardness and Toughness

To illustrate, window glass is hard, but not tough. It will scratch very hard steel, but will shatter under a light blow. Untempered iron is tough, but not hard. It can be ground away rapidly by a stone, or scratched with glass, but it is extremely difficult to break by pounding or twisting.

To some extent stones possess the same qualities, and in addition almost all of them have one or more lines of weakness. Most rocks have a grain, not unlike the grain of wood, and will split more easily along the grain, and less easily in any other direction. It is safe to say that all rocks have joints running in one direction, and some rocks have two sets of joints running at right angles. The joint lines may not be visible, but the force of a blast or of a sledge will find them. There is still another sort of weakness in rocks with which the blaster should be familiar. This is the bedding plane, or layer—with lines running at right angles to both joint-lines mentioned.

Some knowledge about the joints and natural cleavage planes makes the breaking of rocks easier. Even the most massive rocks are divided into blocks of varying sizes, making them split in some directions easier than in others. The cracks will tend to stop short and splinter out or to run entirely through the stones, depending on the toughness of the rock, while the blocks will or will not crumble much according to their hardness.

Description of Rocks

In these brief remarks we will make no attempt to give the geological classification of the rocks, but will try to identify the typical rocks found as boulders and ledges by names which are used most generally, and to make
Two fields which will cost $50 to $200 or more an acre to clear of stumps and stones. If the land can be used for residential purposes or for some form of intensive farming like trucking or fruit growing, it will pay to clear such places, but it will not pay to clear them for general farming and pasture purposes.

clear their nature. Common names for different kinds of rock or stone are not always satisfactory because the common name applied generally to one kind of rock in certain localities in numerous instances is applied to an entirely different kind of rock in other localities, but it is hoped that any confusion will be limited.

These three classes of rock seldom exist as boulders, though they sometimes interfere with cultivation in the form of ledges close to the surface of the ground. In this shape they nearly always are full of two sets of joints, and lie in thin beds. Sometimes the seams are so close together that the rock breaks up into blocks only an inch or two square. They are fairly tough, are inclined to crumble rather than split or crack, when struck with a sledge hammer, and are easy to drill.

Usually takes the form of flat boulders on the surface in fields or of ledges which project almost to the surface or above the surface several feet. Limestone generally has two systems of joints. It also has bed lines wide apart—a foot or more. This kind of stone nearly always is tough, breaking off, rather than splitting far. Its hardness varies.

The boulders of this class frequently are nearly round. Slate rock is characterized by a thin shingle structure. The leaves are less than a quarter of an inch thick. There are joints as well. The stone is tough, breaking only a short distance (but splitting on cleavage lines easily), soft, and inclined to crumble.

Occurs as boulders of every shape and size, and as ledges of all sorts. The ledges usually are stratified—that is, in beds of a thickness of 1, 2, 3 or more
feet. It has frequent joint lines running in two directions, and it breaks up into irregular sized blocks of more or less rectangular shape. The Sandstone sand particles which compose the stone are very hard. When the cementing material is silica the stone is blue or white, and much harder than when of an iron origin, making a brown or red stone. For purposes of drilling, blue sandstone must be classified as a hard rock, and brown sandstone as softer rock; and for breaking purposes, both kinds may be listed as soft. It crumbles easily, and is rather tough.

These rocks and others like them in structure lie in layers from 2 to 100 feet thick. They have no other bed lines, but they have infrequent joint lines. Lava, excepting that of the pumice type, is hard and brittle. The boulders split fairly easily into pieces of irregular shape and size.

A mixture of various rocks, such as slate, sandstone and the like, often in the form of pebbles cemented together, making a rock that lies in beds. It may be crystalline and very hard—even flinty—or it may be only medium hard. The boulders are rather brittle than tough. Joints in one direction are located wide apart. Boulders of conglomerate rock sometimes have a ball-like structure, with layer after layer 1 to 6 inches thick, and joints every 2 to 4 inches. The layers of such rock crack off like the skin of an onion.

 Occurs often as boulders, though frequently there are granite edges. Granite is of a massive structure, with frequent joints. It splits easily. It is hard to drill. Some granite breaks easily while other is difficult to shatter.
Some rocks are full of irregular cavities resembling General Features bubbles, and these generally make the breaking easier. The cavities interfere with the regular joint lines and cause the splitting to take place along new lines of weakness.

The amount of force required to break a rock depends on its hardness and its relative toughness, and on the lines of weakness or cleavage which run through it. Hard rocks usually crumble less easily than soft rocks, but generally split better when once started. Tough rocks are hard to split into small pieces, while brittle ones shatter to bits under a proper blow.

The point at which the force should be applied for the most and quickest breakage depends on the structure of the rock and the direction and frequency of bedding and joint lines.
Methods of Clearing Away Rocks

Rocks too large to be pried out and loaded for hauling by hand, and tight ledges, must be broken. Following are described eight methods of breaking them. Each method has advantages under certain conditions, but some are much more serviceable, convenient and easy than others under most circumstances.

List of Methods

Hauling: Consists of either dragging with chains or loading on sled or wagon. See page 31.

Sledging: Consists of hammering them into pieces small enough to handle. See page 14.


Plug and feather breaking: Intended for splitting out building stone. Consists of drilling a series of small holes in a line across a boulder, and then driving into these holes special steel wedges.

Blasting by drilling: Called "blockholing" when referring to boulders. See page 23.

Blasting by undermining or underdrilling: Called "undermine blasting" or "snakeholing." See page 19.

Blasting by mudcapping: Also called "doby shooting," "plastering" or "blistering." See page 15.

Choice of a Method

In the practical handling of rock clearing, the elements Cost, Men, Time and other Factors to be considered are the costs of labor and material required. These are governed by the nature and amount of rock to be broken. Time is also an important factor.

The softer and more brittle boulders, if they are not large, may be disposed of by any of the above methods. Very hard and tough rock cannot be

How a boulder can mar the appearance of a farm from the roadside view. Such a stone leads possible buyers of a place to think that the field contains many such.
sledged into pieces successfully. When such rocks are to be blasted they should be drilled (blockholed) rather than mudcapped or undermined. Ledges of rock always should be broken up by blasting drilled holes. The limits of size of rock at which mudcapping becomes impracticable are explained on page 15.

Labor conditions are important. On some farms men are very scarce and wages are high. At other places there are periods when laborers are practically idle and can be put to disposing of stones, without much extra cost. In the former case it is wise to let explosives do all the work possible with no more drilling, sledging, handling and hauling than absolutely necessary. In the latter case the amount of explosives used should be kept down, and the idle men left to do the resulting extra work.

The time element is equally important. If nothing else demands the attention of the men on the farm, a slow method is all right, but when stones must be removed in a hurry, the quickest method probably is the cheapest in the end.

When the cost must be kept down as much as possible, and when easier and better methods are not available, burying and breaking by fire may be resorted to, provided there is labor available at little cost. Sledging, when practicable, is a cheap method if labor and time are not considered, provided good sledges are available. But it is slow, hard work. This applies to any way of disposing of rocks except blasting. If the conservation of energy as well as of time and men is desirable, the use of high explosives is the only method to consider.

Mudcapping is the easiest way to blast boulders in most instances, but takes the most explosive of the three blasting methods. It seldom should be attempted with boulders containing more than 5 cubic yards of stone unless they are thin slabs, and is expensive with trap rock or other very hard and tough material. Rocks should be flat rather than round, or at least should have a flat side on which the charge can be placed.
mudcapped a few days later with five cartridges with the result shown in the second picture. Note that the entire rock has been reduced to small fragments requiring no further handling.

Undermining or "snakeholing" has practically the same effect as mudcapping, though it requires less explosives and, usually, a little more work. Blockholing, though effective and economical, requires time and tools to drill the holes.

Mudcapping and undermining are pre-eminently the methods to use where there are only a few boulders to dispose of, since one man can do in an hour by these methods what it would take much longer to do by any other method. Stones that are deeply imbedded should be undermine blasted lightly to roll them out, or at least to loosen them, before they are mudcapped. Some very large stones should be both undermined and mudcapped, with two or more charges fired simultaneously with an electric blasting machine.

Other combinations of methods will suggest themselves to a resourceful blaster.

Study the rock. If it is imbedded, roll it out by undermine blasting as above directed, and examine it on all sides. Usually you will find that an undermined or mudcap blast, unless the charge of explosive has been small, will break up the boulder and make blockholing unnecessary.
Detailed Directions for Disposing of Boulders

Small boulders, weighing only 100 pounds or so, may be dug out and rolled into wagons on planks, or dragged off the field with chains. With larger stones, hauling is slow business, and is likely to result in injury to men. The hard straining required to lift the rocks, added to the danger from the falling of heavy stones, makes what would seem to be one of the simplest and safest of jobs an exceedingly hazardous one.

A practicable method of disposing of rocks is to break them up with sledgehammers. Use heavy sledges—the heavier the better. The tough rocks are almost impossible to break in this way. It is impractical to sledge up large rocks of any kind.

Pay particular attention to the direction of the grain and the lines of cleavage. A blow right at a vital point often will break a rock in two when you could hammer away an hour at another part without much effect.

When you sledge rock, there is much danger from flying bits of stone, and it is a good plan to wear gloves. Tie your coat sleeves over the gloves or the gloves over the sleeves, turn your collar up, wear a cap which pulls down over the ears, and wear goggles. If you have no goggles, be careful to shut your eyes when striking the rock.

One way is to dig a pit alongside the stone, and tip it over. This is suitable for stones that can be pried over. Large stones must be undermined and let sink down slowly. Let each end down separately. Extreme care must be used in this operation to prevent the rock from rolling on the man who digs. Burying heavy stones is a dangerous operation, and has crippled and killed many a man.

Burying rocks is open to the objection that at some time the work may have to be done over again, on account of not getting the top low enough. Frost, erosion, and other forces gradually have the effect of bringing the stones to the surface. If the rock is large, it will interfere seriously with the growth of anything planted over the spot. Buried stones are beyond your reach if needed for building purposes.

The easiest way of breaking stones is to do it with high explosives. The directions for this work are here given in full detail, with careful attention to mudcapping, blockholing and undermining or "snakeholing," and to combinations of these.
Blasting Boulders and Ledges

All of the methods described in the preceding chapter are more or less useful, but in actual practice the disposal of boulders or ledges nearly always will be impractical unless you use explosives.

Mudcapping Rock

Briefly, mudcapping rocks consists in placing the explosive in a neat pile on a face of the rock, covering it with about 6 inches of stiff wet clay, and exploding it. When done right, the force of the explosion breaks the rock.

It is the enormous speed of the gases which accounts for the success of such a blast—the time element. Mudcap blasting is made possible by the intensely fast shattering action of some of the modern high explosives. It cannot be done satisfactorily with black powder nor with the slower kinds of high explosives.

Owing to the resistance of the air and the inertia of the material in the mudcap, the gases strike the rock like an enormous sledgehammer swung at a rate faster than the eye could follow. Such a blow, if in proportion to the size and strength of the rock, is sure to shatter it.

Of the three distinct methods of blasting, mudcapping is

Description the best one to use when the boulders to be broken are flat and brittle and smaller than 5 or 6 feet across.

Probably the most economical mudcapping per cubic yard of rock is in blasting sandstone boulders having flat sides, and containing 4 to 6 cubic yards. Some sandstone is brittle, yet hard to drill, therefore should be broken by mudcapping. Shale, slate, conglomerate and other such rocks break very successfully under mudcap blasts. Mudcapping is less satisfactory, owing to greater quantity of explosives required, when very hard and tough rocks such as trap, etc., are to be broken. In fact, mudcap blasting had better not be attempted on hard, tough rocks that are more than 3 feet in diameter unless no drills are to be had, and the stone must be removed immediately.

If the stone lies free on the surface, it is ready for the placing of the explosive. If it is buried in the ground more than a foot, it is a good plan to dig or blast away the dirt before attempting the mudcap blast. One way to do this is to dig a trench round the stone, to within a few inches of its bottom. Another way is to place one or more small charges down alongside the stone and to loosen the dirt or throw it away from the sides, but in such a way as to leave the ground firm and undisturbed underneath. A third, and probably the best way where the stone is almost buried, is to explode a slightly larger charge down under one side of the stone to roll it out of its bed, and onto the surface of the ground. Then it is ready for mudcapping.

In determining the best point at which to place the explosive, consideration of the principles of rock structure, as outlined on pages 7 and 9, should be the basis. Study the make-up of the rock and determine the directions in which it will split the easiest.

Locating the Place for the Charge

Look for and work for the hair-thin but far reaching seams. Clean the dirt or dust from likely-looking places. The joint lines most of the time will be hardly visible, yet they are important if the most complete and economical breaking is to be secured.

Some workers say that they put the explosive where they would hit the stone with a sledge if it would be possible to break it with one blow. The big
thing is to get the explosive at a vulnerable point on the rock, whether this is top or sides. It may be necessary to support the explosive and its covering of mud with a banking of dirt, or with props from the ground, if the charge has to be located down along the side.

It is better to place the explosive in a depression or hollow on the stone, or at least on a flat face, than on a round or bulging surface. A round face acts to some degree as an arch, and resists the blow of the explosive much more than a flat face. A depression gives the explosive some confinement that enables it to do better work.

In placing the explosive it sometimes is well to deepen crevices or depressions with a drill or cold chisel, in this way making what might be called a semi-mudcap out of the blast. Such a blast is more efficient than when the explosive is placed on a flat or rounding surface. If it is desired to break the boulder or rock into pieces of certain shapes and sizes, make channels across the face with a chisel or mason's hammer and place the explosive in these channels. The process is like breaking ice by chopping channels across it. This treatment gives rough dimension pieces, but it may increase cost.

The charge of explosive ordinarily should be placed in a low cone at the point selected on the rock. If less than four cartridges are to be used, it is well to take all the explosive, except \(\frac{1}{2}\) cartridge for priming, out of the paper wrapping and press it into place. If the charge is large, one or more of the cartridges can be left intact and bedded in loose explosive. Sometimes the cartridges bed-in better when cut in two. The explosive should not cover much area on the stone, since widely spread charges tend to distribute their force and have lower breaking ability. Sometimes it is a good plan to place the explosive

How a mudcap charge is pressed down on a flat side of a boulder, with fuse projecting from the mud, and how a boulder is broken up. This charge was placed properly and was of the right amount. Note that none of the pieces were thrown far, though the stone is well broken up.
in a long, narrow mass—if there is a long depression, or crack, or the rock is much longer than it is broad. Thin edges of the mass should be pressed in and made steep and square.

Before all of the charge is in place, put in the cap with fuse or the electric blasting cap. See pages 143 and 150. The best way is to prime a part of a cartridge of explosive in the usual way and bed this in the

Inserting Cap loose explosives. If you decide to do this, stand the primed powder on end, with fuse or wires projecting from the top, and the closed end of cap pointing toward the center of the whole charge and then press the rest of the loose explosive about it.

If a primer of this kind is not used, the cap must be inserted directly in the charge. To do this punch a hole a little larger round than the cap about one-third of the way down in the top of the charge. The cap should be in the upper third of the charge. To place the cap deep in the mass might lower the efficiency of the blast.

Use the handle of the cap crimper or a blunt-pointed stick for punching the hole, as directed on page 147, and see that the cap is pushed to the bottom of the hole and that the explosive is pressed closely around it.

The covering of mud should be put over the charge carefully. Be sure that the cap is not pulled out of the explosives during the covering operation, or later.

The mud cap should be, preferably, of stiff wet clay. If clay cannot be got conveniently, use the heaviest earth you can find.

The Mud Covering Sand is the least satisfactory material, but can be used if made thoroughly wet. In any case, the mud-cap must be MUD and not dust.

At least 6 inches of mud cover should be placed over the explosive. This means 6 inches of covering in all directions over all of the charge. If the charge is 6 inches broad, then the mudcap would cover at least 18 inches of the rock, with the charge centered under it. To make a mudcap when the surrounding ground is dry, it is a good plan to gather and mix the mud in an old dishpan or box. Then to apply it on the rock simply turn the pan or box over at the right place and press the mud down so that no possible air spaces remain between it and the explosive or the stone. Be careful that there are no stones in the mud covering. They fly like bullets when the charge is fired.

The amount of explosive to use depends on the size and shape of rock and on its toughness and hardness. Below is a table which will serve to guide the blaster. These figures should be high enough to

Amount of Explosive cover tough stones. Less explosive may be used for rocks that are easier to break. Rocks smaller than one cubic yard require more explosive than their size-proportion.

Approximate Number of Pounds of Explosives Required for
Madcapping per Cubic Yard of Rock

<table>
<thead>
<tr>
<th>Material</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandstone, slate and similar soft or easily broken rock</td>
<td>1 lb.</td>
</tr>
<tr>
<td>Limestone and other intermediate rock</td>
<td>1 1/4 lbs.</td>
</tr>
<tr>
<td>Marble, trap, granite and similar hard tough rock</td>
<td>2 lbs.</td>
</tr>
</tbody>
</table>

While this table serves as a basis for calculating the amount of explosive required to break boulders, it is only approximate, as the weight of the charge does not continue to increase according to the number of cubic yards in the boulder. Some blasters may prefer the following table, which gives the approximate number of cartridges required for each diameter of stone.
Number of 11/4 x 8 Inch Cartridges of Explosive Required for Mudcapping Boulders of Different Sizes

<table>
<thead>
<tr>
<th>Sandstone slate and similar soft, more easily broken rock</th>
<th>Limestone and other intermediate rock</th>
<th>Marble, granite, trap and hard, tough rock</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/2 ft. greatest dia. 11/4 cartridges</td>
<td>11/2 cartridges</td>
<td>21/2 cartridges</td>
</tr>
<tr>
<td>2 &quot; &quot; &quot; 11/2 &quot; &quot;</td>
<td>2 &quot; &quot; &quot; 3 &quot; &quot;</td>
<td></td>
</tr>
<tr>
<td>21/2 &quot; &quot; &quot; 3/4 &quot; &quot;</td>
<td>21/2 &quot; &quot; &quot; 31/2 &quot; &quot;</td>
<td></td>
</tr>
<tr>
<td>3 &quot; &quot; &quot; 2 &quot; &quot;</td>
<td>21/2 &quot; &quot; &quot; 4 &quot; &quot;</td>
<td></td>
</tr>
<tr>
<td>4 &quot; &quot; &quot; 4 &quot; &quot; &quot; 5 &quot; &quot;</td>
<td>5 &quot; &quot; &quot; 7 &quot; &quot;</td>
<td></td>
</tr>
<tr>
<td>5 &quot; &quot; &quot; 7-10 &quot; &quot;</td>
<td>7 &quot; &quot; &quot; 3-10 &quot; &quot;</td>
<td></td>
</tr>
</tbody>
</table>

Charges in mudcap blasting may be fired by either Firing Charges fuse and caps or by the electric method. The advantages of each method are discussed on pages 159 to 164. The electric method is the only one that can be used when more than one charge is to be fired at the same time.

The kind and grade of explosives best to use for mudcapping rocks is one having a very quick action of great shattering or disruptive power. The best explosive for this purpose is one of 40%, 50% or 60% strength. The straight nitroglycerin dynamites are a little quicker in action than the “extra” or ammonium nitrate explosives, and for mudcapping should be the first choice. See page 153. But the ammonium nitrate dynamites are equally powerful, when of equal percentage strength, and though they are slower in action, tending to break the rock into larger pieces than nitroglycerin explosives, their work is satisfactory for mudcapping.

When another explosive than those recommended above is on hand on account of some other use, it may be used for mudcapping with success, though its use may be more expensive. Almost any high explosive for farm, mine or quarry work, may be used in an emergency. Even the 20% high explosives that are best for soil blasting can be made to break rocks in this way, though their performance will not be very satisfactory. When these lower percentage explosives are used, particularly if of the ammonium nitrate type, the quantity must be increased greatly. The use of such explosives will result in cracking the stones into a few large pieces rather than into many fragments. Whenever there is much mudcapping to do it will pay to get the proper explosive. In cold weather, use only the low freezing grades of these explosives.

The only tools necessary for mudcapping are a shovel, a pocketknife and cap crimper, though an old dishpan or similar receptacle and a water pail often can be used to advantage.

Breaking average sandstone boulders by blasting by the mudcap Method on some jobs has cost fifteen to twenty cents per cubic yard. Granite, limestone, marble and trap rock boulders have been broken for slightly lower Cost and Time more. Mudcapping costs per cubic yard of rock run up fast when the boulders are very large, say larger than 6 to 8 cubic yards each. Trap and other tough rocks are expensive to mudcap. The shape of the rocks has much to do with the cost and practicability of breaking them in this way.

The approximate cost of mudcapping can be computed on the basis of the amount of dynamite required as given in table on page 17. The time required to mudcap rocks is very little. When wet ground for the mudcap is at hand, a man can have a stone lying round in pieces within 10 or 15 minutes after he
gets on the ground. Many practiced blasters use no more than 5 minutes for each boulder.

Three feet of fuse burns about a minute and a half and under ordinary conditions is enough to permit the firer to reach a place of safety. If an electric blasting machine is used, the operator should stand at least 250 feet away, and should watch for and dodge any flying piece of rock coming in his direction. Avoid standing behind a shelter that may let stones through, as the branches of a tree. See page 164 for discussion of misfires.

A rock will often break better if it is jacked or pried from the ground and allowed to rest on small stones under the ends or corners. Sometimes odd shaped rocks, particularly if they are long, are broken better with two or more mudcap charges placed at different points and fired simultaneously by the electric method, than by one charge. Usually it will be best to locate such charges on opposite ends of the rock, though this rule is not good every time. Sometimes one may be a mudcap and the other a snakehole or undermine charge. Before proceeding with any mudcapping, read the chapter of this bulletin beginning on page 152, about the nature of explosives, detonation, tamping, freezing, thawing, etc.

The result to be expected from a successful mudcap blast is to break the stone into a great many pieces, none of them too large to handle. If a heavy blast is used on a small brittle stone, half or more of the stone may be almost powdered, and few or none of the pieces may be much larger than a man’s fist.

Two pictures: How a proper undermine blast can be made to break a stone that is partly buried. Two charges of 50 per cent. ammonia explosive were used under this stone, and fired simultaneously, with the result shown.

**Undermine or Snakehole Blasting**

To break a stone by the undermine blast method, the charge of explosive is placed against the under side or bottom of the stone with the solid ground as its backing. Less explosive is required than with a mudcap, since the confinement is better, owing to the earth backing and the weight of the stone.

This method is superior to mudcapping because less depends on the shape of the stone under the ground or the depth it is buried, which are always hard to determine with certainty.
Undermining or snakeholing works better when the stone to be broken has a flat side down, and with flat boulders rather than round ones.

To shatter a stone by this method, as by other methods, due attention must be given to the hardness, toughness and seams.

Locating the Holes as outlined on pages 17 and 19.

When a boulder is well buried the first thing to do is to probe about it with a sharp quarter-inch steel rod, to learn the shape of the under side and the condition of the ground. In any case, the charge of explosive should be placed as near as possible underneath the center of weight of the rock.

Holes for the explosive can be made with a crowbar and sledge or with a dirt auger. The crowbar likely will be the most serviceable. If the hole is not large enough to hold all the explosive required at the right point, you can make use of a scraper to enlarge the hole at the bottom. See page 61 for illustration. In blasting very large rocks, small tunnels can be shoveled out.

The practice of enlarging the bottom of the hole by "springing" with an inch or so of a cartridge of explosive, is seldom to be recommended in undermine blasts of stones, on account of possibly enlarging the cavity too much and forming cracks extending into the surrounding earth.

The explosive should be placed as nearly against the rock as possible. When the rock is undermined by digging, the explosive should be packed in a compact bulk, as in a mudcap charge. If you get the Placing the Charge an inch or two away from the rock with dirt between, its breaking effect on the rock will be reduced. Read the directions for loading a hole, on page 28, and for placing a mudcap charge on a rock, page 16.

The cartridge of powder containing the blasting cap should be the last or next to the last to go in. The cap should not be against the rock, but if possible in the outside portion of the charge. The business end of the cap should be pointing directly toward the center of the charge.

The charge must be thoroughly and tightly tamped. If there is not good firm resistance all the way round it will blow the dirt out from under the rock without doing any stone breaking at all. It is a good plan sometimes to tamp the dirt the whole way round the stone before the charge is exploded. Never use a metal tamping rod in the hole or near the charge of explosive. It may strike sparks from the rock or from small pieces of stone, and cause a premature explosion.

Firing the charges may be done either by the cap and fuse method or with electric blasting caps and blasting machine. Each method has its advantages and adaptations to certain conditions as fully explained on pages 159. Firing to 164. How to prepare charges, including the fixing of the fuse and cap, inserting and tying them in the cartridge of explosive and other details, are told on pages 142 and 151.

The amount of explosive required to shatter rocks by the undermining method depends on the size, shape, toughness and hardness of the rock. The table here will serve as a guide. These figures Amount of Explosive should be high enough for average tough rock, but it must be remembered that the amount of explosive required does not always change according to the size of the rock to be blasted.
Approximate Number of Pounds of Explosives Required for Shattering Boulders
“Snakehole” by Undermine Blasting, per Cubic Yard of Rock

Sandstone, slate and similar soft or more easily broken rock ........................................... 3/4 lb.
Limestone and other intermediate rock ........................................... 1 lb.
Marble, granite, trap and similar hard, tough rock ........................................... 1 1/2 lbs.

Some blasters may prefer a table based on the diameter of the stones. Such a calculation can be used satisfactorily, but in this case, too, a great deal depends on the shape of the boulder.

Approximate Number of 11/4 by 8-inch Cartridges of Explosive Required to
Shatter Boulders of Different Sizes by Undermine Blast

<table>
<thead>
<tr>
<th>Sandstone</th>
<th>Limestone and other tough rocks</th>
<th>Marble, granite, trap and similar very hard, tough rock</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1/2 ft. greatest dia.</td>
<td>1 1/4 cartridges 2 1/2 cartridges</td>
<td>1 1/4 cartridges 2 1/2 cartridges</td>
</tr>
<tr>
<td>2 &quot;&quot; &quot;&quot; &quot;&quot;</td>
<td>&quot;&quot; &quot;&quot; 3 &quot;&quot;</td>
<td>&quot;&quot; &quot;&quot; &quot;&quot;</td>
</tr>
<tr>
<td>2 1/2 &quot;&quot; &quot;&quot; &quot;&quot; 1 1/2 &quot;&quot;</td>
<td>&quot;&quot; &quot;&quot; 3 &quot;&quot;</td>
<td>&quot;&quot; &quot;&quot; &quot;&quot;</td>
</tr>
<tr>
<td>3 &quot;&quot; &quot;&quot; &quot;&quot; 1 1/2 &quot;&quot;</td>
<td>&quot;&quot; &quot;&quot; &quot;&quot;</td>
<td>&quot;&quot; &quot;&quot; &quot;&quot;</td>
</tr>
<tr>
<td>4 &quot;&quot; &quot;&quot; &quot;&quot; 3 4 &quot;&quot;</td>
<td>&quot;&quot; &quot;&quot; &quot;&quot;</td>
<td>&quot;&quot; &quot;&quot; &quot;&quot;</td>
</tr>
<tr>
<td>5 &quot;&quot; &quot;&quot; &quot;&quot; 6 7</td>
<td>&quot;&quot; &quot;&quot; &quot;&quot;</td>
<td>&quot;&quot; &quot;&quot; &quot;&quot;</td>
</tr>
</tbody>
</table>

If larger sizes are to be broken, better calculate the amount of explosives required by the cubic yard basis. Your figures will be more accurate. When rocks are to be rolled out without shattering, comparatively small charges can be used. The following table will give an idea of the amount of explosive necessary.

Approximate Quantity of Explosive Required to Roll Out Buried Boulders

<table>
<thead>
<tr>
<th>1 1/2 ft. dia.</th>
<th>1 1/2 cartridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 1/2 &quot;&quot; &quot;&quot; 2 1/2 &quot;&quot;</td>
<td>&quot;&quot; 2 1/4 &quot;&quot;</td>
</tr>
<tr>
<td>3 &quot;&quot; &quot;&quot; 1 &quot;&quot;</td>
<td>&quot;&quot; 1 &quot;&quot;</td>
</tr>
<tr>
<td>4 &quot;&quot; &quot;&quot; 1 1/2 &quot;&quot;</td>
<td>&quot;&quot; 2 &quot;&quot;</td>
</tr>
<tr>
<td>5 &quot;&quot; &quot;&quot; 2</td>
<td>&quot;&quot; 2</td>
</tr>
</tbody>
</table>

Larger sizes than listed require proportionately increased charges.
The extent to which the boulder is buried and the nature of the ground also influence the amount of explosive required.

Probably the most economical explosive for breaking rock in this way is 30% to 50% strength dynamite of either the nitroglycerin or ammonium nitrate class. On account of the better confinement secured in this method, stones can be broken more effectively and successfully with slower and less powerful explosives than by mudcapping. 20% to 40% strength dynamite often

Kind and Grade of Explosive

A striking illustration of the action of a proper under- mine blast. The rock is lifted a few feet and cracked, but is not thrown far. Look closely and you can see the cracks where they had begun to form at the instant the picture was made.
will prove satisfactory. Any standard strength of nitroglycerin, ammonium nitrate or gelatin dynamite will do the work.

To roll stones out without breaking them, the high percentage explosives can be used successfully, but they are not as well suited to the purpose as the slower ones, such as 20% ammonium nitrate dynamite. If you are buying explosives for breaking rocks, however, buy those best suited to the actual breaking, and do the rolling out of the stones with the same explosive.

The tools needed in snakehole or undermine blasting of boulders are the testing rod or probe already mentioned, a shovel for handling dirt, a crowbar or dirt auger, a wood tamping rod 1\(\frac{1}{4}\) inches in diameter, and a cap crimper. Several other items in the tool list can be made use of to good advantage where there are many stones to undermine. One is a 3-inch fence post, to tamp the ground tight about the edges of the stone. Another is the scraper, for enlarging the bottom of an auger hole.

Undermine or "snakehole" blasting is a slightly cheaper method than mudcapping when conditions are favorable. It is often found that the cost per cubic yard increases with stones smaller than one cubic yard, and is very much less with stones containing several cubic yards. Sandstone and other such easily broken material can be broken up cheaply, while marble and trap come higher. Although the cost of explosives is somewhat less than with the mudcap method, this is partly offset by the additional labor required in making the holes in the ground. Ordinarily a man can make a hole and place a charge under a stone in 15 to 20 minutes.

Combinations of snakeholing and mudcapping sometimes are effective with stones that lie on the surface of the ground or are imbedded only a little.

A combination of evils. Such loading could not result in breaking a boulder. Note the seven faults.
To make use of the advantages of such a combination an electric blasting machine to produce simultaneous exploding is necessary. It is not wise to attempt the combination of top and under shots when a stone is buried deeply. Better roll it out first.

Two points of caution are desirable. Beware of misfires. See page 164. Remember that snakehole or undermine blasting may throw pieces of rock with considerable force and range, but the danger can be reduced to a minimum if proper precautions are taken to see that every person and animal is out of range of flying rock and fragments. It is not unusual in snakehole or undermine blasting to see pieces of stone thrown more than 100 yards.

**Blockholing**

This method of breaking rock with explosives consists in drilling a hole into the boulder, putting the explosive at the bottom, tamping tightly, and firing in the usual way. It is remarkable how small a charge of explosive will break a big boulder, even of the hardest and toughest kind, when placed in this way. One cartridge of explosive in a drill hole 18 or 20 inches deep in a rock will do more damage than several cartridges on the surface.

The blockhole method of blasting is the best way of breaking large, tough boulders that are not too hard to drill and which do not break well from a surface blast.

Drilling and blasting in a similar way is nearly always the only practicable method of blasting ledge rock.

The nature of the rock has a good deal to do with the point at which it is best to place the explosive. Ordinarily it will be found that the charge should be located somewhere near the center of the boulder, though different kinds of rock require different depths of holes. A brittle rock which does not split well and a tough rock such as trap, must be drilled deep in order to break it right, while a shallow hole will give satisfactory results in a rock which is easy to split, or which crumbles apart like slate.

A rule that may be applied to all rock is that the deeper the drill-hole, down to $\frac{1}{2}$ or $\frac{3}{4}$ the way through the rock, the less explosive will be required, and the greater will be the execution of the blast. In boulders that are very hard, and so big that they require a large charge, it once in a while pays to drill a very small hole, and then spring this hole at the bottom by exploding at that point a small charge of explosive, using no tamping. Such a practice will be needed rarely in boulder blasting, though it is often useful in blasting out ledges.

Holes may be drilled by one man alone, or by two or more men. One-man drilling usually is the cheapest when holes are made by hand. The drilling can be done with ordinary hand hammer drills, with churn drills (finishing deep holes), or with machine drills.

A hand drill is just a straight piece of drill steel, which is medium hard and very tough, with one end shaped into a proper cutting bit. This bit is $\frac{1}{8}$ to $\frac{1}{4}$ or more wider than the shank of the drill, with the cutting edge somewhat rounded up to the corners and sharpened in the form of a "V," the angle of which should be long and thin or short and thick, according to the kind of rock to be drilled. In soft rock use a long thin cutting edge; in hard rock a short, thick edge.
You can buy drills of different lengths and diameters from mine supply houses or hardware dealers anywhere. Or you can buy the steel from hardware stores and make them. Drill steel comes in $5/8$-inch, $3/8$-inch and other diameters, in bars up to 20 feet long. If you plan to make your own drills, be sure to have on hand a good length of it, for even if you have only a dozen boulders to blast you will need several drills as they require sharpening frequently.

If one man is to do the drilling, the hand hammer should weigh 3 or 4 pounds; if two men, 8-pound sledges are about right. All hammers should, of course, be flat faced. The drill should be turned about $1/6$ of a revolution at each stroke of the hammer so as to keep the hole round. The more regularly this is done the nearer true the holes will be and the faster the bit will cut. The holes can be started with a short drill—say 8 or 10 inches long—easier than with a long drill.

The right diameter for a hole in a boulder usually will be about one inch. It is well to keep the hole as small as possible, for it takes a good deal longer to drill a big hole than a small one. For instance, it takes about four times as long to drill a 2-inch hole as one an inch in diameter. If the 1-inch hole will contain enough explosive it should be the size selected. But it must be remembered that as the hole goes down, the ears of the drill bit will wear off and the hole will grow smaller, so that in hard rock it is well to start a hole that is to go deeper than a foot or so, with a drill $3/4$ inch larger than is wanted at the bottom. In boulders containing more than 6 or 8 cubic yards of material it is best to drill inch or inch and a quarter holes.

The holes should be kept wet by pouring in water as the drill goes down. In this condition, the drill cuts much faster than in dry holes. It is necessary to keep the holes clean. The sludge, as the ground-up rock is called when mixed with water, can be taken out with a scraper which is shaped somewhat like a very small garden hoe, or with a spoon rod, which is a small wood rod with a disc of tin on each end. The discs should be of different sizes, and at

Pressing in the tamping after a charge of explosive has been seated in the bottom of a blockhole.
one point they should be cut to the center and one of the cut edges bent down, so that when the rod is revolved in the bottom of the hole the edge will scoop up some of the sludge.

Another good way of cleaning out holes is to use a spiral hook, or drag twist, like an old-fashioned rifle cleaner. Rags or hay can be used on this to wipe the hole. A hickory or willow stick with the end split into many small pieces, or broomed, is also a good thing for getting dirt out. When this is dipped in the sludge, the material sticks to it, and can be lifted out and knocked off against the outside of the stone.

A leather or rubber washer, or some old rags, should be fixed round the drill just above the level of the stone, to prevent the sludge and dust from flying up into the face of the driller. This is particularly necessary when churn drilling.

A churn drill is a piece of drill steel from 5 to 6 feet long, often having bits at both ends. It is used without a hammer—a man raises and drops it into the hole. Holes cannot well be started with it. It will cut Churn Drills holes faster than a hammer drill under favorable conditions, but owing to the way it is worked its use should not be attempted in holes less than 6 or 8 inches deep. For deep holes and in soft rock it certainly should be considered. A good churn drill for 1-inch holes should weigh about 10 pounds.

Bits should be kept sharp, for dull drills do only a fraction of the work they should. To sharpen bits costs about five cents each. It may be done in a blacksmith shop or, in emergencies, with a file or on an emery-wheel or grindstone. They should be made as sharp and hard as

Sharpening Drill Bits they can be used in the rock to be drilled without either dulling too fast or chipping. The angle of bevel that is best generally will be about 90 degrees for hard rock and 45 to 60 degrees for soft rock. Your blacksmith will give you the proper kind of bevel if you give him the necessary information. Good drill steel is not tool steel.

Before attempting to sharpen a drill the shape of a new bit should be observed. Heat the drills to cherry red, and do not hold them long at that temperature. Work to get them hot without delay, then take them out of the fire promptly for dressing.

The bit should be hammered to shape on the anvil, with the Shank of the drill held so that it has 1 foot rise to 2 feet of length. You likely can use a file to advantage to help shape the edge, while the steel is hot. When the bit is shaped, it is ready to be put back into the fire and reheated for tempering.

The tempering should be started when the steel is at a temperature of 430 degrees F. You can tell the temperature by the shade of the surface or color film that forms on the surface as the steel is being heated.

Tempering Drills When the bit has been heated slowly until the surface has nearly a cherry red shade, take it from the fire and hold it in the air till it gets a very pale yellow. Rub it on a stone to remove the scales so the color can be seen unmistakably. If it seems to take too long to reach this color in the air, plunge it into the water and out again at once to start the cooling. Then watch the colors by standing in a dark corner. They should advance parallel to the edge. If they don’t, hold the hot corner or side in the water an instant to even up the entire bit. As soon as the very pale yellow color is noticed, stick the bit into cool water and leave it there, stirring it about till most of the heat has left the steel.
Temperatures of the steel that are indicated by the colors are as follows:

<table>
<thead>
<tr>
<th>Color</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very pale yellow</td>
<td>430 degrees F.</td>
</tr>
<tr>
<td>Straw color</td>
<td>470 &quot;</td>
</tr>
<tr>
<td>Brown</td>
<td>490 &quot;</td>
</tr>
<tr>
<td>Purple</td>
<td>530 &quot;</td>
</tr>
<tr>
<td>Full Blue</td>
<td>560 &quot;</td>
</tr>
<tr>
<td>Dark Blue</td>
<td>600 &quot;</td>
</tr>
<tr>
<td>Cherry Red</td>
<td>900 &quot;</td>
</tr>
</tbody>
</table>

How a proper blockhole blast will shatter a boulder into pieces of all sizes. Note how completely the stone is broken throughout its entire volume and not just at one side or corner.

The time in which two men with hand drills can make holes in rock can be told best by stating the number of minutes it takes per inch of hole in different kinds of rock. For beginners, when two men are drilling holes an inch in diameter in rock such as sandstone, about 2½ to 3 minutes per inch in depth is required; in limestone 3 to 3½ minutes; in granite 4 minutes; in mica schist 5 minutes; in marble and trap rock 6 to 8 minutes. Single hand drilling (one man) proceeds about two-thirds as fast, except that in soft rock the rate is upwards of three-fourths as fast and in very hard rock only half as fast. These figures change greatly according to the experience of the workers and the condition of the sandstone, limestone, granite, schist, marble or trap rock that is drilled.

Machine drilling is very much faster than hand drilling, and much cheaper where there is enough drilling to do to justify the purchase of an outfit. Since there are many owners of large acreage which requires clearing, also many contractors in stump and stone removing who will use this handbook, some of the data about machine drilling will be useful.
In clear rock, or rock not checked, machine drilling is 5 to 15 times as fast as hand drilling. In some sandstone it is possible to go down at the rate of a foot in 5 minutes (instead of an inch or two as in hand drilling); and in trap rock at the rate of a foot in 10 or 12 minutes. In limestone the rate is even faster than in some blue sandstone, there being records of instances where a foot has been drilled in 3 minutes. Hard granite and flinty rock often drills at the rate of a foot in about 7 minutes.

Blockhole blasting is more economical than undermining, the cost depending partly on how difficult the rock is to drill. Blockholing requires a smaller amount of explosive and larger amount of labor and time than mudcapping or "snakeholing."

The cost of machine drilling usually is much lower than of hand drilling—often it is about one-fourth or one-third, of course not including depreciation or interest on the cost of the outfit. This is much or little per foot of hole drilled, according to how steadily the outfit is used. It may amount to only a fraction of a cent, or it may run the total cost up higher than that of hand drilling.

How a boulder can be broken into pieces small enough to handle easily without shattering it into fragments, with proper charges of 20 per cent. ammonia explosive placed in a blockhole, or by 40 per cent. explosive used as a mudcap. This stone shows by its breaking how joint and bed lines run.

There are two types of machine drills operated by steam or compressed air—the small jack hammer type and the large tripod drill. The jack hammer drill is the best type of machine for use on boulders. Jack drills are portable and easily handled. Tripod drills are heavy.

The tools needed in blockhole blasting, aside from drills and hammers, are a pocket knife for cutting fuse or scraping wires, a cap crimper and a wood rod for tamping. Crowbars are often useful.
The kinds and grades of explosives that can be used for blockhole blasting are many. In fact, rock can be broken by this method with almost any blasting explosive. But certain facts should be understood by blasters. One is that the use of a high strength quick-acting explosive, such as 50% or 60% dynamite will shatter rock into small pieces, while the use of slower explosives such as 20% strength will crack and split it into larger pieces. Ammonium nitrate dynamites are considered somewhat superior to nitroglycerin explosives for this purpose. For the ordinary breaking of boulders into pieces small enough to handle easily, there is nothing better than 20% to 40% ammonium nitrate dynamite.

In blasting in quarries, 5 tons of rock often are brought down per one pound of explosive. It is difficult to maintain this ratio in the field, unless it be with very large rocks, or ledges with an open or free face. Small boulders often require more explosives per cubic yard than large ones. The shape of the boulder is also an important point, so the following tables can only be considered as approximate.

**Approximate Number of Pounds of Explosives Required to Break Boulders by the Blockhole Method.**

<table>
<thead>
<tr>
<th>Per Cubic Yard of Rock</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandstone and other more easily broken rock</td>
<td>( \frac{1}{4} ) lb.</td>
</tr>
<tr>
<td>Limestone and other medium rock</td>
<td>( \frac{3}{8} ) lb.</td>
</tr>
<tr>
<td>Marble, trap and similar hard, tough rock</td>
<td>( \frac{1}{2} ) lb.</td>
</tr>
</tbody>
</table>

Figuring on the basis of the diameter of the stones and the number of cartridges of explosives required, the tabulation is:

**Approximate Number of Cartridges of Explosive Required to Break Boulders of Different Diameters**

<table>
<thead>
<tr>
<th>Sandstone, Slate and similar easily broken rock</th>
<th>Limestone and other medium rock</th>
<th>Marble, Granite, Trap, and similar hard, tough rocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(\frac{1}{2}) ft. dia. (\frac{3}{4}) cartridge</td>
<td>(\frac{1}{4})-(\frac{3}{8}) cartridge</td>
<td>(\frac{1}{2}) cartridge</td>
</tr>
<tr>
<td>2 &quot; &quot; (\frac{3}{8}) &quot; &quot;</td>
<td>(\frac{1}{2}) &quot; &quot;</td>
<td>(\frac{1}{4}) &quot;</td>
</tr>
<tr>
<td>2(\frac{1}{2}) &quot; &quot; (\frac{1}{2}) &quot; &quot;</td>
<td>(\frac{1}{2}) &quot; &quot;</td>
<td>1 &quot;</td>
</tr>
<tr>
<td>3 &quot; &quot; (\frac{1}{4}) &quot; &quot;</td>
<td>(\frac{1}{2}) &quot; &quot;</td>
<td>1 &quot;</td>
</tr>
<tr>
<td>4 &quot; &quot; (\frac{1}{2}) &quot; &quot;</td>
<td>(\frac{1}{4}) &quot; &quot;</td>
<td>2 &quot;</td>
</tr>
<tr>
<td>5 &quot; &quot; (\frac{1}{2}) &quot; &quot;</td>
<td>2 &quot; &quot;</td>
<td>3 &quot;</td>
</tr>
<tr>
<td>7 &quot; &quot; 6 &quot; &quot;</td>
<td>8</td>
<td>10</td>
</tr>
</tbody>
</table>

Often from experience, an observant man will learn just how much explosive is required to crack a stone and lay it apart without excessive throwing of pieces, danger and waste of explosives.

All water should be wiped out of the holes. If the holes are smaller than the cartridges of explosive the paper wrapping of the sticks will have to be removed and the explosive pressed into the hole so that there are no air spaces. The cap should be placed in the charge near the top. Tamping of damp or wet clay or other earth should be placed solidly over the explosive to the mouth of the hole. Results of the blast with the smallest charges will be poor unless there is at least 6 or 7 inches over the powder.
An undermine blast that was too heavy was used here to break a very hard, tough boulder. As a consequence the rock is broken only into large pieces and these are thrown long distances. A better way would have been to have used a very heavy mudcap blast on top of the rock, or, still better, a proper blockhole blast.

The firing of blockhole charges may be done either with fuse and cap or by the electric method. If more than one charge is to be fired, the Firing electric method will enable you to put them all off at once. Electric firing is of much advantage in blasting out ledges, and also in firing the very small charges sometimes used to break stone to certain dimensions. Sometimes what may be called a "semi-mudcap" blast can be used in very hard stone, or in stones that are difficult to drill. Drill a hole into the stone for 3 to 8 inches, fill with explosive, let the rest of the charge of explosive pile up on top of the rock as you would a mudcap charge, in a low cone with steep edges. Cover this with 6 inches or more of wet clay.

Boulders that are buried may be thrown out of the ground before they are blockhole blasted. When the earth is supporting them on all sides they may not break quite as well. Digging round them or raising them off the ground with a jack or pry, and letting them rest on small stones placed under the ends or corners, helps to break them up better.

Blasting in drilled holes is practically the only method that is effective in breaking up ledges of rock, either underground or above the surface. Drill a line of holes along back of the edge or face of the ledge above the surface. It is not necessary to dig or blast away the dirt from a ledge. The quantity of explosive required can be gauged by the table giving the amount to use per cubic yard of rock. Use half again as much explosive in a ledge blast as in a boulder. Measure the distance from the open side or face of the ledge back to the drill holes, and compute the number of cubic yards that should be broken off.

Ordinarily on farms or in roads it is desirable to break up ledges to a depth of about 2 feet below the surface. To do this the holes should be put down slightly more than 2 feet and should be located 2 or 3 feet back from the face of the ledge. To break ledges deeper, drill deeper holes farther back from the
face and charge heavier. The deeper holes can also be farther apart. Two-foot holes usually can be 5 feet apart in soft, brittle shale and slate, 4 feet apart in limestone, and 3 feet apart in harder material. The spacing between the holes should be about the same as their distance back from the face. The details of charging holes, drilling, tamping, firing, etc., that have been given for boulder blasting apply equally to ledge blasting.

Blockhole blasting is perhaps the most efficient method of breaking rock that is known, and from it you can expect perfect results. If you use a proper charge of a quick explosive, the rock will be shattered into small pieces. If you use a slow explosive, the rock will be broken into larger pieces. In any case, the use of the charges recommended here will result in the satisfactory breaking up of any rocks you may have to deal with.

Results to Expect

How boulders are shattered into fine pieces by heavy mudcap charges of 60 per cent. nitroglycerin explosive. Note the amount of stone that is so small it will not need to be hauled away.

General Considerations

The information on boulder blasting, and particularly on the breaking of ledges of rock, applies to quarrying limestone or road material, gravel, etc. In quarrying, it is better to drill larger holes than one inch.

Quarrying

Proper loading in inch and a half holes, drilled to depths of 6 or 8 feet, and 5 or 6 feet back from the edge of the quarry ledge will loosen large quantities of rock.

It does not pay to dig hard-set gravel or sand by hand, for in such material the holes are easy to drill, and comparatively small charges of explosive will loosen great quantities. For quarrying use 40% ammonium nitrate explosive unless the rock is wanted in large pieces, when 20% ammonium nitrate grades will be better. For the semi-rock, hard gravel, etc., use 20% explosive, the granular powder known on the market as R.R.P., or if the work is dry, black blasting powder.
Emphasis should be placed on the possibility of using explosives as a labor substitute. To illustrate, take the disposal of a 4-foot sandstone boulder. To drill this with an inch hole 32 inches deep would require about 1½ hours, or slightly less, for two men. But one man can smash the same boulder within 10 minutes by placing a proper mudcap blast. In the first case the breaking of the boulder is achieved with greatest economy in total outlay, but in the latter case it is broken by one man, and broken without interfering seriously with other work. On many farms there is so much to do and men are so scarce that to take the 1½ hours for the boulder’s removal is out of the question, and the boulder remains in the field—unless it can be broken up with little labor and loss of time.

When a boulder that is nearly all buried is rolled out and blasted, there likely will be room in the hole for many of the large pieces, deep enough to put them all below the plow line, but it is not well to bury pieces larger than 6 inches in diameter, as the broken rock will be valuable for building purposes, for road making, lining ditches, etc., and should be kept in the stone pile until needed.

Disposal of Pieces It costs about 35 cents a cubic yard to haul pieces of stone away, figuring on the average haul. Solid rock of average density weighs about 2 tons to the cubic yard and loose material as it falls weighs about 1½ tons to the cubic yard. It is better to put a stone rack on a wagon if a wagon is used. Such a rack can be made of 2 or 3 inch plank. To get heavy pieces of stone on the wagon, use planks to skid or roll them up. If the pieces are very heavy, use a “stoneboat” instead of a wagon. It is better for short hauls because it saves so much lifting. An average load of stone is about a ton and a half, and two men will handle this in about half an hour, including loading and unloading.

Hauling The holes from which boulders have been taken should be filled level, to avoid a low place in which water will gather during wet weather. To fill the depressions, a horse drag scoop such as is used in excavating dirt is a useful thing. If this is not available, a good thing to use is an ordinary road drag, or a split log. By standing on the drag or log it can be made to gather a lot of ground, and the dumping can be done by taking off or shifting your weight.

In addition to various tools described under the separate headings on methods, blasters of boulders will find a heavy crowbar and an iron wedge to be useful at times for prying apart pieces of rock. Some blasts will be found not quite heavy enough to throw the stones apart, but a little prying will accomplish more than a whole lot of hard hammering. If the bar cannot be forced into the crack use the wedge and sledge it in. Be careful that the wedge does not strike solid rock at a bed or joint line running at right angles. The wedge should be a slim piece of tough steel, 6 inches long and an inch or two thick at the base.

Steel bar for making holes.

Soil auger—note long point.
The best tamping material is damp clay. Tamp the hole full, while working in the tamping with the stick in one hand, hold the fuse or the electric wires out of the way with the other hand. It is easy to damage fuse and wires by breaking the insulation with a pebble, or with the edge of the tamping rod. It is also easy to pull the cap out of the primer charge unless the fuse or wires are held firmly against the rock. Many misfires are due to carelessness at this point.

In lighting a fuse, stick the flaring head of a burning match right against the powder in the end. See page 159. This will work in any wind. The fuse always gives a pronounced spit as soon as it is lighted. Do not leave before the sparks and smoke begin to spit out regularly.

It may be safe to stand 100 to 150 yards away from a blast that is not overloaded, but this is a matter which each blaster will have to decide for himself. Much depends on the proportion of the charge to the boulder, its location, and whether the stone is solid. The right charge will not throw stone far, but a charge that is too heavy, or in the wrong place, will throw large pieces for long distances. In fact, this is one of the ways in which you can tell whether or not you are using too much explosive. In any case, to be safe, keep an eye on the blast and dodge any flying fragments coming your way.

Use every care to keep everybody beyond the range of danger. The man who fires the charge should keep his eyes open for stones coming down several seconds after the blast and at distances 100 yards or farther away. They are dangerous. See page 164 for discussion of Watch Misfires their cause and remedy.

How a large granite sandstone or limestone boulder can be shattered with a mudcap blast. At the point next the explosive the stone is broken into small fragments, but at the other side it is left in large pieces, though it is well cracked in every direction.
CLEARING LAND OF STUMPS

To Clear or not to Clear

A "stump" may be defined as any kind of a growth that obstructs land, whether it is the butt of a cut tree, a tall snag, a living tree or a bunch of sprouts or brush. From the viewpoint of a farmer it is a stump if it obstructs the plowing and other tillage of the land.

Before deciding to clear land, the owner should consider several features of the matter well. The reckless slaughtering of the timber has left in stumps many thousands of acres of land which is not fit for cultivation and that should go back into timber.

When Not to Clear

Such land, of course, should not be cleared. On the other hand it is folly to permit brush land which has good soil to lie idle when a hundred years will not develop profitable timber on it.

Much land that is in woods now should be left so, for timber and for fuel. Every farm should have its timber tract, where the forest is conserved in a way to make it permanent. To cut young growth that will make good timber in a reasonable time is a mistake, no matter how good the soil is. Remember, too, the wind-break value of a piece of woods adjoining farm land, and consider the effect on land you now farm of taking away the protection afforded.

Do not clear land where the soil is too stony to be cultivated to advantage, or land that is exceptionally steep or incurably swampy. Do not clear when the profits would not justify the clearing. And do not clear when you can buy equally good improved land for less than the cost of clearing.

There is a certain sentimental satisfaction in clearing and cleaning up one's own place, connecting fields and improving it generally, even though such improving will not add greatly to the actual money income from the crops. This will have a bearing in some instances.

But hard-headed judgment should not be swayed too much by sentiment, for there are a good many thousands of acres that have been cleared and now are parts of farms, which it would be wise and profitable to plant to
forest again. Lay out your clearing carefully. Include no corners, gullies or steep places you will afterwards neglect. And make sure your field is rightly placed in relation to the rest of the farm.

A fertile looking field which could not possibly pay a net profit of more than half what it should so long as the stumps remain as they are. Two or three years’ gain in crops, or less, would pay for the blasting out of the stumps.

About new clearing there may be some question, but about taking out stumps in good cultivated land there can be none. There are stumps in fields and along fences, roads, hedges and on home grounds. There are pastures that are pastures and not wheat fields or orchards because cultivation among the stumps is too inconvenient. There are old fruit trees and old shade trees that are diseased and a menace. All these should come out, and the quicker they come out the better.

Worth little even as pasture land, never rising in value, but potentially worth $100 an acre as soon as it is cleared. This is the sort of valley floor that makes splendid fields of oats, corn, alfalfa and other hay.
The Profit and Loss Account of Stumps

The man who is taking up the farming of cut-over land knows that he cannot do much until the stumps are removed. But lest he be tempted to permit some of them to remain in the cultivated fields, as many men on older farms are doing, it is well to point out some of the losses which stumps cause and some of the gain which their removal brings.

No farm is well ordered when its fields are foul, and no farmer commands the respect of his neighbors when stumps are crowding out his crops. The loss in self-respect probably is even more serious.

In farming stumpy fields a man does not have that sense of having done his best, which is half the battle for success.

Tool breakage is another source of loss caused by stumps. Plows and furrows are broken, mowing machines and binders are both broken and racked and in some cases the use of machinery is prevented. Heavy engine tools cannot be used at all where there are roots in the ground.

Greater speed and ease of cultivation is a prime reason for taking out stumps. The use of gang plows, wide harrows and other modern labor- and time-saving equipment and methods is practical and economical only on land that is clean, both above and below the surface. And such use is becoming of more and more importance, as farm wages go higher and labor becomes scarcer.

The injury to horses often is much greater from a money standpoint. Spavins and sprains result from jerks against roots. Mares are caused to slink foals, young horses are made balky. The danger of injury to men is by no means absent. The kick of plow handles rupture many men, and every year sees its quota of broken arms and legs among farmers who try to plow, cultivate or mow among stumps.

Weed spread is a thing that must be charged up to stumps. They grow about the stumps, mature seed and pollute the whole farm.
Just as the presence of stumps tends to lower the value of land and to keep it down, clearing off the stumps will raise it and keep it on the increase. Once start to clearing away the stumps on your place and the neighbors and people who pass on the roads will take it for granted that the place is a paying proposition, worth developing. If you want to sell it, there is no surer way of adding a few hundred or a few thousand dollars to the selling price. To hold stump land for increase in value is a mistake. Clear it up and force the increase.

The actual gain in crops to be secured by the removal of stumps can be measured by the proportion of the total ground that they occupy. For instance, in many cases a stump takes up a square rod of ground. In measuring the value of the removal of stumps, the gain in crops and in speed and ease of working the ground should be compared, not with the total value of the crop, but with the net profit before stumps are removed. Thus, if a 25-bushel crop of wheat costs 20 bushels to grow, the addition of 5 bushels to the yield will increase the net profit 100 per cent. Two dozen stumps to the acre may occupy such a large part of the acre that their removal will double the net profit.

The clearing up of land can be made to mean something more than the financial profit it brings, for when properly handled it well can be made one of the links that hold the boys to the farm. Once a boy has helped to develop a property in a way that he enjoys he will remember that place as home as long as he lives. And boys will be enthusiastic over the clearing operations, with the necessary planning for new fields, the blasting and stump pulling, and the burning afterwards, if the work is managed along some of the newer lines which take out the drudgery.

The Essentials of Good Stump Removing

Before settling on a plan for removing stumps, it is well to have clearly before you just what is required.

This is the typical appearance of much land that is very fertile and which would pay handsomely if in alfalfa or fruit. (Near Linville Falls, N. C.)
The stumps must come out entirely, or at least deep enough so that roots never will catch plows or other implements. Stumps with roots must be disposed of as profitably as possible, used if possible, or burned cheaply. They often can be sold or used at home for firewood of some kind, or sold for extract purposes. Failing this, they must be burned on the ground with as little damage to the soil as possible. In any case they must be broken into pieces small enough to handle by hand, unless derricks and power are to be used to handle them.

The total money expense of the clearing project must be within the capital available for the purpose, and the labor and time required must not exceed the supply. The condition in which the ground is left also is important. The holes should be shallow, and the less littering and tearing up of the surface there is, the better. The work usually should be finished in time for planting a crop in the spring, for the loss of a year's time costs money.

These are the things which should be included in the plans for clearing.

Nature of Stumps and Conditions Affecting Their Removal

There are about 500 different varieties of trees which make stumps in America, and it is not advisable to classify them all in this bulletin. What is of value is to review the nature of their roots.

There are three general types of roots—lateral roots, semi-tap roots and tap roots. (See cuts, pages 53 to 55.) Some varieties of trees always grow in one way; other varieties grow in either of two ways, depending on soil conditions. The stumps of some trees rot fast, while others are very durable. Some roots die when the trees are cut; others throw up sprouts. The wood of some roots is tough and can be twisted a great deal without breaking; of other varieties it is brittle and will break off when bent or jerked.
Typical tap-root stumps are long-leaf southern pine, hickory and black gum. Some of these trees grow a root that is almost as big as the trunk, extending straight down into the ground. Others have slender roots. Sometimes these tap-roots send out lateral roots of some size, but in other cases the laterals are limited to hundreds of short, hair-like rootlets growing from the main tap-root. The tap-root itself sometimes splits at a point several feet underground into several smaller roots, all of them continuing to grow nearly straight down.

Typical lateral root stumps are elms, soft maples, locust, dogwood, elder, hemlock and some cypress. The roots of these trees grow in all directions from the trunk near the surface of the ground. Working the ground close about such stumps is next to impossible.

The largest class of stumps is the semi-tap-root class. Belonging to this class are white pine, poplar, chestnut, ash, walnut, red, black, pin and other oaks, persimmon and sassafras. Stumps of this class are harder to remove than either of the other two types, because the roots generally are big and strong and grow in all directions, some along the surface, others almost straight down and still others between.

What may be classed as a fourth division is composed of the root clusters of sprouts and bushes of almost any sort of trees, whose growth has not yet taken the characteristic form. Brush of willow, elder, maple, chestnut, hickory, oak and witchhazel may be named. The roots are very firmly anchored in the ground for a distance of three or four feet in all directions.

The nature of the soil and the height of the water-table in it have much to do with determining the root growth. A hemlock tree, for instance, will send its roots down till they almost take on the nature of the semi-tap-root class in soil that is loose, free from stones and dry. The same tree would have few roots deeper in the ground than 6 inches where the soil is hard and the water-table near the surface. The root growth of other varieties of trees

Wonderfully productive meadows, for timothy, alfalfa or other grass, can be made by cleaning up and draining stump flats. This land was a tangle of old logs and stumps a few months before the picture was taken. (Michigan Land & Lumber Company.)
is affected by water and soil in the same way. A tree that grows on a steep hillside probably will have heavier roots on the sides than on the downhill and uphill grades.

A glimpse of primeval forest and of primeval stumps, the like of which few farmers meet in the eastern part of the country any more. Such land is expensive to clear but it is exceptionally fertile in most cases.

Some stumps are durable and others will rot very fast. White pine, Norway pine, locust and cedar stumps will last fifty years without decaying enough to make much difference in the work of their removal. Chestnut, white oak and catalpa are nearly as durable. The other oaks, poplar, ash, hemlock, hickory and gum rot so fast that in a few years a team of horses can roll out stumps of considerable size.

It should be understood that during the first season, after any variety of tree is cut and the stump and roots die, the bark and soft outer layer of wood rots away, making the roots loose in their earth channels. It is the inner or mature wood which lasts.

Another characteristic of stumps which is of importance in clearing plans is their sprouting. None of the pine stumps will sprout when a tree is cut, but nearly all the hardwood stumps will do so. Chestnut is a great sprouter. A stump that does not sprout is not getting any worse as time passes, but one that does sprout is likely to be harder to take out each succeeding season.

All kinds of stumps pull easier when the ground is wet than when dry. Explosives are more efficient in wet ground than in dry. Pulling machinery ordinarily is handicapped in very wet ground, because of the lack of firm footing.

The nature of the soil, whether light or heavy, has a considerable effect on the way stumps come out of the ground. Naturally a loose, fluffy sand will hold the roots less than heavy clay. Pulling them out
This clump of trees was blasted out (not cut down). The stumps are torn out better than they might have been without the weight of the tops to pull them over.

of sand, therefore, is much easier than out of heavy soil. On the other hand, light soil will not confine the gases of explosives nearly as well as clay. In sand the greater ease of tearing the roots loose is more than offset by the lowered efficiency of the blast.

The foregoing principles should be of more actual service to land clearers than a description of the conditions in different sections. If your stumps are Southern long-leaf pine, you know they will not sprout, and are of the tap-root class. If they are white pine of Michigan or Maine, you know they are of the semi-tap-root class, that they will not sprout and that they
When stumps are lifted by frost as much as some of these, they often can be pulled economically. They should be split up afterwards with light charges of explosive placed in auger holes or between roots, under a mudcap.

probably will outlast you if you do not move them. In case of a locust stump in Oklahoma, you know that you have a lateral root stump to deal with, that will sprout and that will last as long as the white pine. These illustrations serve to point out how every reader can classify his own stumps as to facts about them that are important from the clearing standpoint.

Methods of Clearing Land of Stumps

A half-dozen methods of removing stumps are more or less well developed throughout the country. Everyone who clears land, whether it is only the removal of stumps from cultivated fields or the clearing up of logged-off areas, should study the different systems in order to decide which of them is best under any particular conditions. No one method is best all the time, and in nearly every case a combination of various means will be found most effective.

Lists of Methods

Digging out the stumps by hand.

Pulling the stumps. The pulling may be done with horses or machines. The pull may be direct, or may be doubled or tripled in force by means of blocks and cable or rope. If with machines, it may be with a traction engine hauling direct, a donkey engine hauling by means of a drum and cable, a capstan puller run by horse power or man power, or a tripod puller which lifts the stumps straight up. (See pages 44 to 50.)

Burning the stumps. The old-fashioned practice was to start a fire alongside a stump and keep it going till the stump was consumed. Charpit burning consists of keeping an intensely hot but small fire about the base of a stump under a covering of earth. Another method is to bore auger holes through the
stump or part way through, to form draft holes and flues. A favorite method in some sections is to burn out the roots with a gasoline torch to a depth below the plow line.

Finally, there is the use of explosives to blast out the stumps. Combinations of methods very often are valuable, and are recommended at proper points.

**Stump Disposal**

The land clearer must remember the necessity of disposing of stumps after they are out of the ground. It is expensive and difficult to haul or burn whole stumps. Several hundreds of pounds of earth nearly always stick to the roots of big stumps taken out unbroken. For this reason wherever it is possible to do so the stumps should be broken into pieces small enough to be handled easily before the job is considered done. There is no comparing the cost of burning stumps, when they have to be piled by means of a derrick, with the cost when they can be handled by hand.

**Choice of a Method**

Whether to remove stumps when they are green or to let them decay a year or more is a problem to be decided by your plans and the uses to which you will put the land. Newly cut-over land is clean. It has few weeds and no sprouts. In one season it will not develop much of this growth, but in two or more seasons it will, and will be very much harder to clear than it would have been the first year.

The stumps are hard to take out while they are green. It costs much more to do the work then than a year or more later, after the bark and sap-wood has rotted from the roots.

But it costs money to miss crops, too, and if you are ready to put the ground to work at once, it is folly to wait for the stumps to rot. To wait from summer till the following spring is not a bad idea, for that loses little or no time, and starts the rotting process which makes removal easier and cheaper.

Speaking in general of pulling and blasting, pulling the stumps probably is better and cheaper when the stumps are very small, and blasting when they are large. Where a large number of big stumps are to be removed a combination of the two methods is advisable.

When stumps are small or numerous they can be pulled by a team of horses hitched direct, by a capstan puller, traction engine or donkey engine, with ease and speed. The pulled stumps can be handled by hand directly, and disposed of without trouble. The same is true to a lesser degree when larger stumps grow small and shallow roots, which require but little power to lift and move.

For stumps larger than 3 to 5 inches, explosives can be used alone effectively and economically, though there are important considerations which modify such a rule. One of them is that of soil. Explosives work more effectively in heavy, tight soil, such as moist clay, than in dry sand. Therefore, in dry, light soil it often is cheaper to pull all the stumps not too large to handle without breaking up, while in heavy soil it usually is cheaper to pull only very small stumps that will come out easily, and to use explosives, alone or in combination, for everything larger.
Old, well-decayed stumps too big to handle should be removed with explosives alone. Small green stumps may be blasted out clean, roots and all, but large green stumps nearly always require a combination of methods, as, for instance, blasting and team pulling, or pulling with a capstan puller. The cost of explosives often can be cut down by making use of such a combination of methods. A heavy team, or other means of pulling, will take out roots after the ground has been loosened with explosives.

Tap-root stumps larger than your arm should be blasted. Tap-root stumps cannot be pulled to advantage, though when very small they can be broken off by a side pull. Where land is swampy on the surface, and roots consequently lie shallow, a heavy team often can rip out stumps by direct pull, even up to fifteen inches in diameter.

Large stumps that are pulled may be broken up afterward with small charges of explosives placed in auger holes, but in general it may be stated that large stumps should be blasted first.

The folly of pulling out stumps that are big, and then spending as much money in getting rid of them as it costs to pull them, will be plain to any one. They can be disposed of at a fraction of the cost when they are well broken up.

A more detailed consideration of the pulling of stumps probably is desirable. Pullers are most successful in the loose jack pine land of the North and the similar pine land in the South, and in clearing hardwood cut-over land where nearly all the stumps are small. They are particularly serviceable where the stumps stand close together, measure 3 to 6 inches and have root systems which do not bring up much dirt. Under such conditions a stump puller is a good investment, especially where there is plenty of man and horse labor available at low cost.

But it does not pay to buy a machine for a small acreage of clearing. It pays only where a considerable quantity of clearing is to be done. In vicinities where the soil is light and there are many stumps on newly cut-over land,
several farmers should co-operate in the purchase of a stump puller and should help one another to use it.

A stump puller works to least advantage under clay soil conditions. Another factor is the water in the ground. The ground must be fairly dry when the machine is used, even though the stumps require harder pulls then when the ground is water-soaked. In mud, horses soon become mired deeply. Pulling of stumps must be done in the summer or fall. Of course, they cannot be pulled when the ground is frozen.

A capstan puller can be used on a moderately steep hill, though the cost of pulling the stumps from such ground will be greater than from level land. Whenever it is desired to use a stump puller, have explosive materials on hand to blow out or to split and loosen any stump larger than about 5 inches.

A donkey engine outfit especially designed for stump pulling can be used effectively and with success. It makes an expensive outfit, however, and unless there are several hundred acres of clearing to do, consideration of it may be dropped. In the case of very large acreage, it is the logical form of capstan puller to use.

A traction engine, pulling stumps direct, is a very effective means of getting stumps out. In fact, when such an engine is available it is doubtful if the purchase of any other machine ought to be considered. Both traction and donkey engine pulling is subject to the same limitations as pulling by any other means, and should be confined to such work as they can do to advantage in comparison with explosives or other methods.

The detailed consideration of the blasting of stumps may be short and to the point. The use of explosives reduces the labor of land clearing greatly. One or two men with explosives can do the work of a large crew with pullers or fire.

The stumps can be blasted out clean. Thousands and thousands of acres of stump land are cleared completely every year with explosives alone. While the use of some means of pulling in connection with explosives undoubtedly cuts down the cost on a large tract of clearing, the added ease and speed of the work of explosives alone is considered by many people to offset this economy. For small tracts or a few stumps it is foolish to provide pulling facilities. Do the work with explosives.

The blasting splits the stumps into pieces easy to handle, and to sell or burn. When it is not desired to blast stumps out clean, the charges can be kept down and the stumps split and the dirt loosened and thrown away from the roots. The blasting does the work in a short time.
The investment of money is kept down when explosives alone are used. There is no machinery or equipment left on your hands after the clearing is done. Yet the best use of stump pullers and of explosives is mainly distinct and different, and they should be considered, not in competition, but in combination. A good team and a supply of explosive material is a winning combination nearly every time, and explosives are bound to play an important part in nearly every land-clearing operation.

Digging out stumps is practicable under certain exceptional circumstances. If you cannot get explosives and if you have men who are doing nothing, they may be put to digging out stumps; but if wages have to be paid, such clearing is bound to cost four or five times as much as when the work is done by better methods.

This pine stump is burning freely, and likely will be consumed if it receives some attention. The roots were bared of dirt and the stump was split by a light charge of explosive. When stumps can be left to dry for a couple of months after such splitting, they will burn very well, though pine stumps can be burned immediately afterward with a little coaxing.

Big stumps such as this can be blasted out electrically much easier and better than with charges fired with fuse.

Burning by charpitting is a practicable and cheap method of getting rid of soft wood stumps of large size and of stumps in heavy or clay soil when the weather is dry for two months or more at a time. It is not successful in lighter soils. It is costly when labor must be hired for the purpose, and wastes time. This method of removing stumps is chiefly valuable for settlers of logged-off or cut-over land who must fight their way through with little or no money.

When to Burn means of auger holes, and the use of oil, are freak methods not suitable for general use. They should not be attempted when the clearing operation is seriously intended to be economical. Burning with a torch of some kind is effective, but expensive.
Detailed Directions for Clearing Land of Stumps

Digging Out Stumps

If you dig right down after the roots, trenching to bare them, cutting them off with an axe first at the sides and then underneath, the stumps can be rolled out as though they were pulled. The cost is high.

If possible to know beforehand that you must dig stumps out, do it before the trees are cut. Dig a trench about them, taking away the support, and cut the lateral roots, and then let the wind and water finish the job. The water in the trench will soften the subsoil. The best time of year to do it is in the spring, when the wind is strong and the ground is loose.

Burning Out Stumps

Charpitting is perhaps the best method of burning stumps. The fire is kept burning at the base of the stump till it burns entirely through, and till the top is consumed as it settles down and the roots are eaten out to a proper depth below the surface of the ground. The fire is confined by a covering of earth.

Charpitting is effective only when heavy grounds can be secured to cover the fire. Sand, loam or other light soil cannot be used for the purpose successfully.

The stumps should be reasonably dry, and the weather should be dry during the burning process, which takes two to six weeks. Light showers are not objectionable, but heavy, settled rains cause failure. Pine stumps burn best, because of the pitchy nature of the sap remaining. Any other soft wood can be burned this way. The successful burning out of hardwoods requires favorable conditions in all respects, and is rather doubtful in the hands of inexperienced operators.
The procedure is as follows: Remove the bark from the base at least. On some stumps it is necessary to dig away a little dirt. The fire should be started low enough so that it will burn in under the stump at the spaces between the roots.

Gather some fuel wood—any kind that will make good coals, though mixed oak and a little pine likely will be best.

**Directions** Cut this wood like stove wood—say about a foot long, and split fairly fine. Lay and stand the sticks round the stump till you have a layer at least 6 or 8 inches thick. You can pile wood and start the fire entirely round the stump, or only about a quarter of the way round as you prefer. Putting wood all round takes more wood and more time to prepare, but burns the stump out quicker and has more chance of success.

After the wood is in place it must be covered with a little straw, fern or other material of the kind, and then with a thin layer of dirt. The dirt layer should not be more than 3 or 4 inches thick. It must be of clay or very heavy soil. The dirt should be piled against the stump up to about 18 inches high, but no higher.

Start the fire at each quarter of the space round the stump. That is, if the wood runs only a quarter way round, start one fire; if all the way round, start 4 fires. Leave the holes where the fire is started open only for a little while, and then cover them up.

The fire must be kept covered all the time and never be allowed to burn into an open blaze. It is really smouldering and coaling of the wood. When the fire blazes much of the fuel supplied is burned up and the heat is lost instead of forced to eat its way into the stump. The object is to confine the heat. When this is properly done the fire becomes intensely hot round the stump.

As the stump burns through and the fire goes deeper, the dirt cover may break through. Such places must be covered with more dirt. If the fire burns higher up the stump than where the dirt is piled in the first place, put it out up there instead of trying to pile the dirt higher.

As soon as the stump is burned through, the top will settle down and continue to burn. Keep the fire covered over the ends of roots that burn off, so it will eat its way deep into the ground. If it breaks out to the air it will not burn far. While the stumps are burning they must be watched and visited several times a day.

The cost of charpitting in the manner described is high when the actual time of the operator must be accounted for at regular rates of wages.

Another good method of burning that really is charpitting of a modified form, is to saw the stumps off close to the ground, block up the top part, and to start a fire between the two sawed faces. The faces should be as close together as possible while allowing the fire to be started and to burn. Bank up the outside with dirt, as directed in preceding paragraphs, and keep the fire covered till the stump, roots and all, is consumed. Use stones to hold the two parts of the stump apart. It is best to do the sawing in the winter and raise the top part then, leaving it to dry out several months. The burning is done best in the summer.
Burning with a torch is simply a matter of digging away the ground from
the roots, and applying the intensely hot flame at a point
below the plow line. Torch burning is expensive business
when time and fuel costs are counted up. The best kind
of a torch to use is one with a fan or bellows. The kind
of fuel used by the torch is not important, except that some fuels burn
better than others. Gasoline perhaps is best.

A modification of charpitting sometimes is advisable in the case of pastur-
ing the land for several years. The stumps are split and their roots un-
covered with small charges of explosives. When they
are thoroly dry, wood is piled between and over the split
tops of the stumps and the whole thing is set on fire.
With a little attention to keeping the burning ends of the
roots covered with ashes and dirt toward the last, stumps
may be consumed entirely by this method. It is not nearly so much trouble
as charpitting, because the fire burns fiercely in the dry, shattered tops, and
needs no attention other than the first piling of the fuel till it is time to look
after the burning out of roots.

Pulling Out Stumps

Four forms of pulling are worth considering. These are by horses direct,
with hand pullers and capstan pullers, and with donkey engines and traction
engines.

A good heavy team of steady horses will take out most of the stumps which
should be pulled whole, and almost any roots left by proper
use of explosives where blasting and pulling are used in
combination. You will need a couple of good log chains
and a regular outfit of singletrees and spreaders. To in-
crease the strength of the direct pull, you can use a
frame made of 6 by 6 pine pieces in the shape of the letter
A. Make it 6 feet high. Attach a short piece of chain round the tip of the A,
to run down to the roots over the top of the stump, or else run the main chain
from the horses over the top of this frame before attaching to the stump. Such
a haul will upset a stump much easier than a direct hitch.

If you have to pull without the frame, aim to pass the chain over the top
of the stump and hitch to a root on the other side, the farther out the better.
Another good hitch and haul is the twist. Hitch to a root and drive so that the
chain tends to wrap round the stump.

When saplings are to be removed do not cut them first, but
hitch the chain to them as far up as you can reach. While the team
is hauling on them, a man should cut the roots on the opposite side with an
axe.

A few days of stump pulling is enough at one time. Rest the
horses and men at some other work. The clearing of land by this method
is heavy and tiresome, and can easily become disheartening if kept up
too long.

A capstan puller consists of a frame, a drum on bearings, a pole to hitch
horses to, and a wire cable fastened to the drum. Some of them have gearing
which reduces the speed of the drum and increases its pulling power. These
work very slowly.
The pullers have to be anchored to solid stumps near the place where they are set up. The limiting factor in the use of pullers is this anchor or anchors. When you pull, you do not always know whether the stump out at the end of the cable or the one behind the machine will come. To set the machine takes time, and you should be careful to make the anchorage as secure as possible.

If your puller comes without a pole, you can get one in the woods near home. Cut a 6-inch tree—ash, white oak, hickory or the like—and use a 20-foot length. Better attach an old wagon tongue to this where the horses are to be hitched, to keep the pole from hitting the horses when stumps give way suddenly. Some operators also attach a second pole in front of the horses, to lead them in the circle, saving continued driving.

It is better to wind up the cable on an empty drum; the cable wears much less in this way. For that reason use only enough cable to cover the drum—not two layers on it. The length of the cable will govern the area you can clear with one set of the machines. This usually will be about an acre.

Three men can clear an average acre of cut-over land of small stumps in one day. Three men will handle a small outfit. Handling the cable is heavy work, and you want no boys on the job. The hooks for catching the roots that come with the machines usually are poorly designed. You can have a better one made by welding together two old steel plowshares in a manner that your blacksmith will understand if you show him the original hook. For best results a hook should weigh about 50 pounds, though to be so light it must contain only good steel.

Pullers are not suited for taking out occasional stumps in cultivated fields, but only to clearing cut-over land where stumps stand close together. The machine should be brought on the job only after the necessary blasting has been done. Then the small stumps and whatever roots are left by the blasting can be taken out at the same time. A supply of explosives should be kept on hand for blasting out the anchor stumps after the machine has done all the work it can.

A tripod puller is effective, but cumbersome to handle and expensive to operate. It is not recommended.

A donkey engine for stump pulling should have about the same power as for logging operations, and should be constructed about the same. There should be two drums, one for the pulling cable and the other for the return line, the return drum geared faster than on a logging donkey.

About 350 feet of pulling cable can be used. Inch or inch and a quarter cable usually will be best. The return line would be half or five-eighths inch. With 350 feet of main cable, 10 acres can be cleared at one setting. It speeds up operations to use a cluster cable with three or four books. Several small stumps can be pulled at once with this.

A donkey engine outfit requires five or six men to operate it. With it stumps of any size can be pulled. When they are too big to handle directly
it is best to break them up with explosives before attempting to burn or otherwise dispose of them. Very large stumps should be loosened and split before they are pulled.

Little needs to be said about using a traction engine. You will need heavy chains and heavy hooks. The chain should be nothing less than five-eighths inch. A short piece of inch or larger wire cable is better. Fifty feet or so is enough. The hook should be of steel, with one point, and should weigh 50 to 100 pounds. The entire hitching apparatus should be strong enough to stand jerking on with the weight and power of the engine.

The cost of operating pulling machines and of clearing land with them varies so much that no figures are safe to depend on. It depends on the kind of soil, the kind of stumps and especially on the skill with which the machines are operated. When everything is at the very best, land can be cleared economically with donkey engines and traction engines in combination with explosives. When conditions are not favorable the cost of these methods is very high.

For any kind of stump pulling you will need shovels, hoes, axes and bars. The probing rod also is useful for locating roots.

The directions for removing stumps with explosives are given in full detail, and in order to do the matter justice they are placed in a separate chapter.

**Blasting Out Stumps**

A proper charge of explosives placed under a stump will tear the roots loose, lift the whole stump out, and break it into pieces. The whole operation is simple, safe, short and easy. Any sort of stump, of any size, in any soil, any weather, can be blasted out successfully, and the blasting is a practical and efficient method whether there is one stump to be removed from the middle of a cultivated field or a lawn, or thousands of acres of the heaviest logged-off land clearing to be done.

The best time of the year to blast out stumps is a matter of compromise between conflicting requirements. On the one hand explosives work most effectively in moist clay and wet sand soils. On the other hand, it is bad from a tillage standpoint to blast heavy ground when wet. (See page 67 for further discussion.)

With all the facts before you, the selection of time is a matter for your own judgment. If cost did not need to be considered, summer or fall would
be ideal. Blasting out stumps from frozen ground can be done with satisfaction. In fact, the stumps are broken up better then than at any other time, though the work is harder on account of the difficulty of making holes.

Success, and especially economy, in stump blasting, is a matter of common sense and judgment plus some knowledge of the stumps and of explosives. Close attention to apparently small matters insures good work. The things that the blaster must consider are the location for the charges, the proper size of holes, the amount of explosives required, the length of fuse, depth of hole, tamping and the like.

Loading Charges of Explosive

To blast out a stump the explosives must be placed in a hole underneath it. Make the hole first. Then prepare the charge of explosives as directed on pages 142 to 150. Pack the explosives in the hole, tamp and fire.

Load stumps by no rule, but with regard to their root systems and to the nature of the soil. The aim is to tear the roots out of their anchorage in the ground, or to break them off below tillage depth. To do this you must place the charge or charges of explosives as close to their burden as possible—hitch them as short as possible to the load. The load or burden is not the weight of the stump so much as its grip on the ground. You must get good confinement of the gases. If there is a weak wall on one side of an explosion and a fairly solid or firm wall on the other, the weak wall will give way, and very little breakage or movement will be made in the other.

The charge of explosives should be located just deep enough to secure this confinement and to be under the load to be lifted, but not any deeper. If
charges are too deep there is great waste of energy in uselessly lifting earth. This is costly. Charges that are placed too shallow will blow off the tops of stumps or split them, leaving roots tight in the ground.

Since clay and other heavy soils hold the gases much better than sand, and wet ground holds them better than dry ground, a much thicker covering of dry sand is required over a charge to confine the gases properly than of wet clay. Charges, therefore, must be placed deeper in sand. Usually the charges should be placed right next to the wood of the roots in clay soil, and in sand with 6 to 30 inches of ground between the charge and the roots (tap roots excepted—see next page). Large stumps, and old stumps, require shallower placing of charges in proportion to diameter than small stumps and green stumps. Long-rooted stumps require deeper placing than short-rooted ones.

With the foregoing points in mind, it will be seen that the charges should be placed directly under that part of the stump that will give the greatest resistance. This may be the center, but it is by no means always so. If the stumps have grown on a hillside, the roots may be heavier cut sideways than uphill or downhill. Very often a tree on the level has heavier roots on one side than on the other. Usually it is of advantage to blast a big stump with more than one charge, placing one charge under each of the large roots and one under the center of the stump. A charge under a root should be at a point where the weight of the stump will be balanced by the pull of the ground at the other end. This point usually will be a foot or two out from the edge of the body of the stump.

In the foregoing suggestions, no mention has been made of the three main types of root growth—tap-root, semi-tap root and lateral root; but with the principles of blasting in mind, it is easy to see that a properly placed charge under a lateral root stump will be very shallow. If such a stump is to be taken out with several charges instead of only one, all but one of the charges will have to be located well out from the stumps proper, under main roots.

Semi-tap root stumps require deeper placing of charges than lateral root stumps. When such stumps are taken out with more than one charge, the points for the explosive are closer in, under the main roots where they dip a couple of feet below the surface.

The underground nature of each stump should be determined before placing charge or even making holes. You can do this partly by observing the roots that rise above the surface, but mostly by probing down among the roots with
the quarter-inch steel needle known as a probing rod. Every blaster should have one of these rods and should make use of it at each stump.

There are two ways of blasting out true tap-root stumps. One is to bore a hole in the wood of the tap-root itself, and the other is to place the charges right alongside the root and against it, as mudcap charges are placed in stone blasting. In placing the charge in the wood, make a hole in the ground down to a point a couple of feet below the surface of the ground. Then bore a hole in the wood with a wood auger. This hole should go two-thirds or three-fourths of the way through the root. Fill the hole in the wood with explosives, fire, and the resulting blast will cut off the root.

In placing the charge of explosives against the wood, get it at least 4 feet deep. If you can command an electric blasting machine for firing, divide the charge in two and place the two parts on opposite sides. These charges may be placed only \(3\frac{1}{2}\) feet deep, though you should not hesitate to place the charges at a greater depth when blasting large tap-root stumps, particularly if the ground is of a light nature.

In all sorts of stump blasting the holes for the charges can be dug with narrow-bladed shovels, spades or crowbars, or bored with dirt augers. (See page 61.) In stony land augers cannot be used, or can be used only for parts of the holes. All things considered, it is hard to beat the bar and sledge combination for making holes for charges of no more than two or three sticks, or for starting holes for larger charges.

The bored hole is better than the dug one because it can be tamped tighter. After much dirt once is taken out, it will not be tamped back in again as solid as it was before. Holes for inch-and-a-quarter cartridges of explosives
should be made with inch-and-a-half augers or bars. In blasting exceptionally large stumps, use 2-inch or 3-inch augers. The holes usually can be started between roots and in depressions, but do not sacrifice good placing of charges for ease in making holes.

In water-saturated ground of a heavy nature, in case you have difficulty in getting the charge properly centered or placed (when no electric blasting machine is available for firing), you can make use of what is known as propagated detonation. Divide the big charge into several small ones in different holes bored from two, three or four sides of the stump, but all ending close together down under at the right point. If these charges are tamped solid and they are not more than a foot apart they all will explode at once when one of them is fired with a cap and fuse in the usual way.

In making holes for blasting out tap-root stumps, start the bar or auger straight down along the root from the surface. When you have reached the required depth, wriggle the bar sideways to make the hole wide at the bottom.

Wherever the number of stumps runs into many thousands, it will pay to get a machine to bore the holes. Such a machine will bore all the holes needed
under the stumps at the rate of 500 or 600 a day, and at very much lower cost than the same work can be done for by hand. The machine bores almost as fast in wood as in earth, and is particularly serviceable when roots have to be penetrated in order to get the charges to the right spots.

**Power Boring**

Machines can be bought complete in small sizes suited to land-clearing purposes, or can be bought in parts and assembled on home-made frames. Electric machines are most convenient. Steam and compressed air machines are next best. Flexible shaft machines and direct-g geared machines are least satisfactory. The flexible shafts break. The steam outfits freeze up and are troubled with burst pipes. All the outfits except steam ones can be run by gasoline engines.

An electric boring outfit consists of a small gasoline engine—say about 5 horse power—on a wagon belted or geared to a 3 kilowatt dynamo, and that equipped with two drill heads and 200 feet of electric cable. A supply of 1½-inch augers completes the outfit. Such an outfit costs about $500. You can use any gas engine. The dynamo will cost somewhat less than $250, and the drills about $80 each.

It takes five men to run this outfit—two men on each drill and one man to drive and to handle the cables. This man should lift the cables carefully over stumps and prevent them from kinking and getting caught. The steam and compressed air and the direct drive machines will not be described, because improvements continually are coming out. Watch the farm papers for advertisements, or write to any maker of explosives for names of manufacturers of these machines, if you are interested in them.
Study the methods of handling explosives as outlined on pages 144 to 150 and 167 to 170, to which every reader is referred at this point, before trying to load charges. A few special hints will be given here.

Charges of explosives usually should be as near as may be in a round bulk—not strung out for 2 or 3 feet in a long hole. To get them so the hole must be enlarged at the bottom by scraping or springing. Slit the paper wrappings of the cartridges and press the cartridges in the hole with the tamping stick till they swell to fit the hole tight and shorten to 2 to 4 inches in length. (See pages 53 to 55.) But do not do this if the hole is very wet.

When you have many stumps to blast out, it often is a good practice to make holes in the forenoon and then to load and shoot after dinner. Load and fire all the holes you have prepared when you go to the field, after which you can proceed to make more holes. Always fire the charges soon after they are loaded. To do this prevents missing charges, and avoids chance explosions due to meddling, and the like. If the holes are wet, firing immediately is required to avoid weakening of the explosive by water.

If you prepare your charges in the field, you can cut a supply of pieces of fuse before you go out. Make the pieces of varying lengths and crimp caps on them to prevent the powder shaking out of the ends. Take the roll along with you to provide for holes requiring longer fuse. Don’t attempt to use pieces of fuse less than 15 inches long. They are dangerous.

Use plenty of earth when tamping the holes, and tamp well. See that the ground is packed solid, not only where you made the hole, but all around the stump. Often there are holes dug by skunks, groundhogs, gophers, squirrels, rats or mice under stumps. Keep the charge of explosives away from these cavities—better fill them up.

In lighting many fuses a gasoline or oil torch is useful. But there isn’t anything much better than to stick the burning end of a freshly scratched match right against the powder in the end of the fuse. (See page 159.) Remember that the outside cover of the fuse does not burn, but the spark runs down the center as a drop of water might run down a tube. Do not leave the fuse till it spits sparks regularly.

None of your charges are likely to misfire if you load carefully, and if you have taken proper care of your explosive materials before loading. But if misfires do occur with fuse, do not investigate them for several hours, at least. (See page 164 for discussion of misfires.) Of course, in electric firing you can
investigate a misfire immediately after the wires have been disconnected at the blasting machine.

Amount of Explosives Required to Blast Out Stumps

A proper charge of explosives for a stump blast has a dead, muffled report. It lifts out and splits the stump. Loud report and the throwing of the pieces far shows that too much explosives has been used. When stumps merely are split and tight roots are left, not enough explosives has been used (or it may be placed too shallow). If the explosion is muffled and does not throw pieces far, but digs too big a hole, the charge is too heavy and too deeply placed.

It is impossible to lay down exact rules for the amounts of explosives to use. This bulletin will include figures of amounts that have been used to blast out some stumps, but these figures must be regarded as correct only under identical conditions of soil, kind and age and size of stump, amount of water in soil, kind and grade of explosives, and amount of confinement in the hole. Experience must be the teacher in this matter.

A green stump requires a great deal more explosive than one that has stood a few years. More explosives are required in stony land than in smooth land to blast out stumps. The harder and heavier the soil is, the less explosives are required, and the looser and lighter it is the more explosives are required. Dry soil requires more explosives than moist soil.

As these roots lie, they show the result of an almost ideal blast. There is little hole in the ground; the stump is well broken up; the roots are cleaned of dirt; and no roots have been thrown very far.

When you want to blast a stump entirely out, it is better to load too heavily than too lightly, for roots left tight in the ground after the top of a stump is blasted off are hard to get out. If you are not familiar with stump blasting, start with the small stumps and load them as you think they should be after considering the various points explained in foregoing pages, and in view of the following figures.

Ordinarily it takes one pound of explosives for each foot in diameter of stump, when the stump is such as a white pine in clay soil cut 10 years or longer. Green stumps of any kind require more than this—usually about half again as much; sometimes twice as much. A rule for the enormous stumps
of the Pacific Coast is to square the diameter of the stump, measured in feet, and use this figure as the number of \(\frac{1}{4}\) by 8 inch cartridges of explosives required. This rule usually over-estimates the amount required for stumps larger than 3 feet in diameter.

Examples of the incomplete job resulting from trying to blast out very big stumps having wide-spread roots, with one charge to each one. Unless the charge is excessively heavy, which means that it is expensive in explosives and in loading, it can not be placed deep enough to remove the whole stump. Even if it is deep enough and heavy enough to be successful it is objectionable on account of the big crater made. Each big stump should have several charges.

Amount of Explosives Used to Blast Stumps

The following table is taken from records of blasting in Minnesota, Pennsylvania, Oregon, Kentucky, Michigan and Florida. The stumps were blown out effectively and successfully, and the figures should serve as a reliable guide.

<table>
<thead>
<tr>
<th>Diameter Stump Inches</th>
<th>Kind Stump</th>
<th>Kind Soil</th>
<th>Cartridges 1 1/4 inch Dynamite</th>
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<tr>
<td>16</td>
<td>Black gum, green</td>
<td>Sand</td>
<td>5(\frac{1}{2})</td>
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<tr>
<td>16</td>
<td>Sugar maple, green</td>
<td>Sand</td>
<td>5(\frac{1}{2})</td>
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<tr>
<td>20</td>
<td>Snag, dead</td>
<td>Sand</td>
<td>4(\frac{1}{2})</td>
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<td>6</td>
<td>Tap-root pine</td>
<td>Sand</td>
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<td>10</td>
<td>Tap-root pine</td>
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<td>12</td>
<td>Tap-root pine</td>
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<td>15</td>
<td>Tap-root pine</td>
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<td>18</td>
<td>Tap-root pine</td>
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<td>18</td>
<td>Tap-root pine</td>
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Proper blasts throw out little dirt. They pull the roots out of the ground, and permit most of what little dirt they do lift to fall back in the hole. In consequence good blasting leaves small holes.

An excellent plan for any blaster is to carry a notebook and a yardstick and keep track of the blasts he makes. Make note of the size, kind, age of stump, kind of soil, amount of water, kind and amount of explosives used, and the result of the blast, in each case.
The figures here given will serve as a guide for the first shots. As the work proceeds, base your loading on your own experience.

Kind of Explosives to Use

The kinds and grades of explosives best to use for blasting out stumps are few, and vary with the nature of the soil. In a heavy soil an explosive which cracks, lifts and heaves is more desirable than one which shatters. In other words, a slow-acting explosive such as 20% ammonia dynamite is the best to use. If the charges must be exposed for some time to water, nitroglycerin dynamite had better be used.

In dry, light soils, such as dry sand, it is necessary to use an explosive that exerts its full force before the gases can give way, as in mudcapping rock. For that reason 50% to 60% ammonia or nitroglycerin dynamite is the explosive to use. Intermediate grades of soil usually can be depended on to hold the gases enough to permit the use of the slower 20% explosives.

The above does not mean that these grades of explosives are demanded for removing stumps. The fact is that stumps can be blasted out with almost any explosives manufactured; but the work can
be done more economically and cheaply if the grades recommended above are used.

Four charges fired together tore this stump loose from its moorings and moved it six feet down the hill, but did not break it up. Another charge should have been located close under the center. It can be broken up easily now, however, by loading one cartridge charge down in the center of the hollow top. THIS STUMP IS A WHITE PINE, CUT 75 YEARS AGO.

The 20% explosives, especially the ammonia, leave the ground in better condition. A violent and quick-acting explosive tears out large holes in heavy ground, and packs the earth about the edges.

Time Required for and Cost of Blasting Stumps

A day's work for one man is 30 to 60 average stumps blasted out. If three men can work as a crew, two making holes and one loading and firing, the number of stumps per man will be much increased.

The cost of blasting stumps is a variable quantity. Those which blast out the cheapest are well-rotted oak or walnut, in moist clay soil. Probably the stumps which cost most to blast are green white pine or oak in dry sand. The skill and good judgment of the blaster also has much to do with the cost.

Tools

The tools you will need for blasting stumps are all common ones. The pictures show better what they are like than words can tell. You can use grubbing hoes, axes, crowbars for driving and for hand use, soil augers, long-shanked wood augers, wood tamping sticks, cap crimpers, water buckets, pocket
This stump came out as a result of a charge that was placed too deep and a little to one side of the proper position, and is not broken up for handling. It can be broken very easily as it lies, by locating a one cartridge mudcap charge between the two large roots seen in the picture. Had the original charge been a foot nearer the surface, the stump would have been broken in several pieces and all thrown out.

This bulletin strongly recommends electric firing for stump blasting whenever there is enough blasting to be done to justify the purchase of a blasting

knives, steel probing rods, adzes, long-handled shovels, spade shovels, spoon shovels, scrapers, spoon bars, sledges and possibly other tools.

An old wood auger does not make a good soil auger, though it can be used in a pinch. For boring in ground an auger should have a leading point 2 or 3 inches long. Both wood and soil augers should have cutting bits that can be filed sharp a good many times without destroying them. Most blasting tools are supplied by all makers of explosives, and by hardware dealers. Some of them can be made at home, by your blacksmith.

The spoon shovel and spoon bars are for tunneling and enlarging bore holes. Make them by turning up and trimming the edges of long-handled shovels. The probing rod is a piece of quarter-inch steel 6 feet long, with one end sharpened to a point. It had better have a handle turned over, or made into a ring. No long description of any of these tools will be given here, because farmers are familiar with them.

A very old white pine stump blown out with three charges fired together electrically. The stump is well torn loose and cleaned, but another charge should have been placed at a point close to the wood under the center, to split the stump for easy handling.
machine. (See pages 159 and 160.) One to fire up to 10 charges can be obtained at a moderate cost. If skillfully handled its use will save its cost for each 500 pounds of explosive fired. Electric firing makes possible work in stump blasting that is superior to the work produced by any fuse firing when conditions are difficult. The several small explosives help one another.

The blaster located his charges under this stump too far toward one side. The result is that the roots of the other side are left sticking in the ground and require another blast.

**General Hints**

To blast out standing trees, use about twenty per cent. more explosives than you would for the stumps. It is better to blast big trees with several charges, firing them electrically.

When big green stumps are blasted out with one charge placed under the

The result of an attempt to blast out a very large green stump with one charge. The explosives were located deep under the center, but they could not reach out far enough to tear loose the many firmly anchored roots. They blew off the top, instead. Such stumps should be blasted with three or more charges all fired together electrically.
center, some of the roots often break off high up, so that they interfere with plows. They are better blasted with several charges placed round the edges. If you are using a stump puller, split and loosen all the big stumps with explosives before pulling them.

It is more expensive to remove severely burned stumps than those with the tops intact. In blasting decayed stumps and those with no tops, fill the center cavity with ground and tamp it tight. Then place the charges in the usual way.

In blasting old rotten stumps that have sound roots, you often find the center underneath has rotted out, or become so that it is only a mass of punk. This material will not hold the gases of the explosives. To blast such stumps, better use an electric blasting machine, and several charges, or if fuse must be used, place the charges under the roots, or deep under the center, filling the hollow center with wet clay or loam.

Old logs and snags frequently are too big to haul or handle and to burn on clearings. Do not waste time cutting them in two, but smash them up with charges of about half a cartridge of explosives placed in an auger hole. If no auger is handy, put a heavier charge in a notch chopped in the log and cover with 6 inches of mud.

Fat pine tap-root stumps often may be shattered by charges of explosives placed in the top-roots, and the stumps left to dry. After a few weeks these stumps will burn like oil pots.

Many farmers can clear their land with very little loss of time from regular work by going about it in a systematic campaign. In an hour or two each evening a good many stumps can be blasted out and the work will be a pleasure. Only one man is needed. By making sure that the charges are rightly placed and proportioned to the stump, the roots all will be broken up so one man can handle them.

Avoid working in the fumes and smoke of blasts, which will cause headache. Also keep the explosives from touching the skin of your hands, by wearing gloves.

When the charge is placed too shallow in the blasting of a stump that is newly cut or that has not rotted much, the top is ripped off, leaving many tight roots sticking high enough to catch a plow.
In removing saplings of sassafras and persimmon and stumps with long, tough roots that may sprout if permitted to break off in the ground, it often is of advantage to explode half cartridge charges a couple of feet under the trunks. This will not take out the trees, but will loosen the ground so that when they are pulled over in the usual way the roots all will come away.

Be careful not to miss charges that are placed, when you are lighting fuse or connecting wires. Get them all as you pass the stumps they are under. Unfired charges are liable to weakening and damage, and are sources of danger.

This is what the stump field should look like after the roots have been blown out. If the land is to be farmed, the next plowing should see every root removed.

Stumps make good fireplace wood and kindling wood. You likely can sell fireplace wood in nearby towns by doing a little advertising or inquiring of people you know. Pine stumps have won a place in the hearts of all American farmers as kindling wood.

Stump Disposal

On nearly every farm and at nearly every home it pays to keep a large supply of pine roots for kindling. Don’t destroy stumps when your wood-house is empty.

At many points roots can be sold as fuel for engines. In many parts of the South stumps can be sold for turpentine extraction. Everyone should make an effort to sell or to use his stumps rather than to destroy them. They represent real fuel value, and a little effort usually will get it out. The home kindling pile can be made big enough to last for years. The roots are ready-cut kindling of the best grade. As fireplace wood they are superior to top growth, because of mineral elements in the sap. They make as good fuel for lime kilns as any other wood. The price for home use near large cities often is upward of $8 to $12 a cord. For turpentine extraction the roots are worth at least $3.50 a cord. Farmers themselves can afford to pay at least $1.50 a cord, with the cost of hauling added, rather than to burn the stumps.

But when stumps cannot be sold or used they must be burned on the ground. Where they have been pulled out, without breaking up with explosives, and are large, the pulling engine or horses must be used to pile them, with the help of a derrick or gin-pole. An engine and a winch, using a cable, is a very good outfit for this purpose. A derrick may be a tripod with legs up to 40 to 45 feet long, or it may be a swinging boom derrick, with mast up to
Wood is a very expensive commodity in many parts of this country to-day. It never will get cheaper. Utilization of all parts of the trees that are cut down in land clearing is the thing to do whenever it is possible.

30 feet high and boom 25 feet long. Let the mast lean a little toward the pile of stumps, so the boom will swing round itself with its load. Another good machine is the Conrath portable piler, much used in Wisconsin. It requires 10 pieces of timber or poles, of which the largest, the two skids and the boom, are 20 to 22 feet long. A gin-pole may be any height that is convenient. An old dead tree makes a good one. Let it burn with the stumps piled about it. With 150 feet of half-inch cable and a pair of double blocks the piling can be done with horses.

A better way to handle stumps than with a derrick is to use small charges of explosives to break them up after they are pulled. When stumps are well blasted the problem of disposal is simple.

Start numerous small fires and haul and pile the roots on as they burn down. The fires can be kept going till all the roots are burned up, by putting on new roots and by shoving in butts. Have a wagon or sled and keep hauling and unloading all the time. Drive about the clearing on regular routes, each time making larger circles and throwing off a few roots as you pass by each fire. One man can clean up more acreage in this way in an equal time than several men working to pile the stumps in high piles with a derrick, except in cases where

The ideal size and kind of pile for burning stumps and roots. These piles can be built by hand, in unloading the stumps from a low wagon or sled. The fires can be started and more roots fed to keep them going.
the stumps are large and unbroken, or are left in very large pieces. What saves expense is piling by hand.

When you clear land by blasting, postpone all burning of brush, logs, etc., till after the stumps are blasted. Then have a grand burning of everything at once. But do not burn the surface—don’t let the fire run over the ground. Keep it strictly to the boundaries of the piles. There is a whole lot of fertilizer in the layer of leaves, moss, twigs and other vegetable matter that every piece of cut-over or logged-off land has on the surface. It is foolishness to destroy this. Plow it down. It is worth a good many dollars on every acre.

When you burn a clearing, first get in touch with the fire warden of the district if there is any forested land at all near your place. Use every precaution to prevent the fire from getting out of your clearing and beyond your control.

You will hear—once in a long while—some man say that blasting out stumps hurts the soil. When you do, tell him he is mistaken. Proper blasting is beneficial to the soil. It is so beneficial that on thousands of farms subsoil blasting is regarded as a standard practice.

Blasting Benefits Soil In many orchard sections no one thinks of planting fruit or shade trees without first preparing the ground for them by blasting. There is a bulletin published on that subject which you should have if you are interested.

It is proper to add here, however, that when the ground is wet a blast does not produce the same effect in it as when it is dry. Subsoil blasting must be done when the ground is dry enough to crumble. Blasting a heavy soil that is in a plastic condition will make it more compact instead of loosening it. It is possible to do damage to a spot in a cultivated field by making a hole there—by digging out a stump, pulling a stump or blasting out a stump—and failing to fill it up level with the surrounding surface.

This bulletin states, correctly, that explosives take stumps out most efficiently when the ground is moist. While this is true, if you want to secure subsoiling benefit to the land at the same time you blast out stumps,
you must do the work when the ground is at least reasonably dry. By blasting the stumps when the soil is not wet you sacrifice some of the efficiency of the explosives in the stump removing, and gain in fertility.

Don't allow the second growth to start at all. Pasture the land with what stock you have. To get goats especially for the purpose is practicable on large tracts, but the small tract had better be pastured by the cattle or hogs or sheep that the farm already has. Goat clearing is advisable only where time is plenty and money for development is scarce. Cut brush to the ground when it is in full leaf. Do the grubbing at intervals through the summer, as time permits. Remember that the grubbing must be deep to kill the roots—a foot down at least.

After the stumps and sprouts are off the land, there still is some work to do before it is ready for crops. New land is fertile, but it usually needs lime. The unevenness and stump holes should be filled after the plowing is done. A small horse scraper is a valuable implement for this, but anything made like a King split-log road drag will do the work. Make a complete job of the leveling. Scrape the bumps into the hollows, and make the surface as even as possible, so that no water will stand in pools. This leveling should be done carefully in old cultivated fields as well as in new ground.

To take full advantage of the big supply of plant food available in the soil of newly cleared land, you must plant crops that will bring in money. This may be a grain such as corn, but is more likely to be hay, cotton or fruit.

Strawberries are pre-eminently a new land crop. They never do as well on old land. If you have marketing facilities for them, put your new ground in strawberries for two or three years.
Potatoes are another paying crop on new land. Corn bears fairly well, but not much better than on old land. Other quick-bearing fruits, such as gooseberries, currants, raspberries and dewberries, do very well. Vegetables like tomatoes, sweet corn, watermelons, beets and squash, succeed very well. Oats is a very bad crop to plant because of the weeds it invariably helps to spring up.

The hay crops are excellent, and in some of them there is a great deal of profit. Alfalfa is the best of them all. If you are planning to plant alfalfa, wait two years after clearing and plowing, meanwhile giving the land a heavy application of lime and cultivating it in some of the other crops named. All the clovers are good. Some people like to sow clover and timothy mixed.

On high land sow red clover and timothy; on low land alsike, timothy and red top grass. Soy beans, Canada field peas, field beans, cowpeas, mammoth clover and sweet clover, cotton and tobacco, all will yield enormous crops on new ground.

If you have cleared in the summer, harrow and disc at once, and sow rye, to be plowed down the next spring if you are going to cultivate the land, or to be mowed if you sow grass seed. The clover should be sowed on the surface of the ground just as the snow leaves in the spring. If you do not get a good stand from the first seeding, do not be satisfied with the poor one, but tear it up and seed over again. You cannot afford to let new ground loaf. There is money in making it work.
These ditches show the result of cutting the sod and the earth along the sides before the blasting. Shovel blades, axes and a hay-knife were used. A man cut a rod along one side in about two minutes. The blast left the soil outside of the cut firm and intact, while scooping the contents of the ditch out clean. (Upper, Miller Drainage District, Marion Co., Oregon; lower, Connecticut land of Polytechnic Institute of Brooklyn.)
THE USE OF EXPLOSIVES IN MAKING DITCHES

The Matter of Farm Drainage

Much draining of agricultural land has been neglected because it has demanded so much money, time and hard work, and so many men. The excessive cost of ditching has retarded plans to drain, and poor methods have retarded actual construction.

In times past ditches have been made largely by hand shoveling. A few of them have been plowed out when shallow ditches could be made to do the work at all. But the digging of a few hundred yards of ditch 3 feet deep has been a summer’s work on a farm, and the draining of land always has been very expensive and hard.

With the increase in the cost of labor, and the scarcity of farm help compared to the numbers of men that used to be available, there is serious need for means of draining that are easier, quicker and cheaper. Since ditching with explosives has become well known and generally practiced, it has come to be the desired method.

Observe the even spreading of excavated earth over the surrounding ground, leaving little elevated bank on the edges of the ditch. Even in heavy, stiff clay such as this, the explosion grinds the earth up pretty fine. (Chester Co., Pa.)

With few exceptions, ditches can be excavated with explosives anywhere. The nub of the whole matter lies in the fact that one of the cheapest ways of moving dirt known is with explosives.

To blast ditches practically all that is necessary is to punch lines of noles and push charges to the bottom. The sides and bottoms of the blasted ditches are not as smooth as if they were shoveled out, but they are even and true, and the flow of water soon levels them down and smooths the bottoms.

The work can be done quickly, neatly and with no expensive outfit. It calls for few men. A month’s work by ordinary methods can be done in a day, or a week’s work in an hour. Ditches can be blasted through any kind of ground except dry sand. The presence of brush, grass, stumps and stones is no bar to this method of cutting out the ditches, though of course they dig out smoother and cheaper when the nature of the ground is clean and clear.

As for size, ditches of almost any desired depth greater than 1 1/2 feet and any ordinary width greater than 3 1/2 feet can be blasted out. Ditches in fields
Representative blasted ditches in sandy loam of the Atlantic Coast section. In such material the charges must be heavy and must be skillfully placed to produce the perfect results shown. With proper care the excavation is satisfactory and the sides more even and true than in clay soils.

(Charleston, S. C.)
and along roads, ponds, canals for drainage or boats, stream channels and similar cuts for any purpose can be blasted out.

This book explains the possibilities of blasting and makes clear the basis on which choice of a method for your work should rest. It shows how to plan and to lay out drainage systems, and how to construct open ditches to the best advantage. Other methods than blasting are recommended frankly when conditions and purposes are such that can be used to the best advantage.

**Conditions Demanding Drainage**

Two classes of farm land should be drained. One is the usual swamp land where the ground is saturated with water or at least is too wet for the growth of cultivated plants. The other class is land now cultivated, but which at some part of the year carries excess water.

The wet or damp lands may be merely low spots in fields, or may be entire valleys. Low spots often can be dried by cutting a ditch through rims of higher ground surrounding. If the wet condition is caused by overflow from streams, the stream channels should be deepened or widened till they carry all the water. If seepage from springs on the land or above it causes the trouble, a ditch cut across the flow of the seepage water will be the proper remedy. If the water-table is too high, a big open drain may gather and carry away the surplus, lowering the surface of the ground water to where it will not interfere with roots.

On account of the matter of moisture storage, as well as on account of general fertility, all land which is cultivated should be drained thoroughly of excess water. It is not enough to reduce the surplus to a point where meadow grass will grow; the drainage must be sufficient to dry off the ground soon after each rain and soon in the spring.

Roads always must be well drained if they are to remain solid and hold their shape in wet weather. Crooked streams should be straightened, to prevent cutting of the banks and overflowing, and ditches and streams too shallow or small to carry the volume of water present should be deepened or widened. Swamp conditions are a menace to health, breeding mosquitoes and their attending diseases. It often pays to drain lowlands where water stagnates, from the standpoint of health and comfort alone, when they are worthless for any agricultural purpose.

**The Value of Drainage**

Good drainage not only removes surplus water but actually helps to store moisture against dry weather. When soil is choked with water, deep rooting of plants or trees is impossible, and the soil processes which make available the plant food are hindered or altogether prevented. It is the absence of air almost as much as the presence of the water that does the damage. The better land is drained to a proper depth in each case, the finer and more mellow and crumbling it will be, and the more of useful moisture it will hold in the summer.

Swamp land usually is very fertile when the excess water is removed, and will grow wonderful crops. It contains a rich supply of plant food. Such land must be aerated—drained—and limed before its fertility can be used.

The direct loss of income from the idle acres in swamps can be figured by anyone. But this is not the only loss. There is the decreased net profit from other land that is farmed under the same ownership. The swamp land costs interest on its purchase price and taxes every year. This cost must be paid by the productive acres.
Two pictures that tell a story of swamp grass damming up a stream, which backs up and floods a field, ruining the hay, or corn or any other crop which may happen to be there. To dig out by hand or plow out such a clogged stream-bed is difficult and expensive, but to blast it out is the work of one man for an hour or so, at a comparatively small cost. (Mud Lick Farm, Julian, Center Co., Pa.)
Winding streams cut up and waste much land. They change their courses every year or so, tear away the banks at the curves, gouge out deep holes and build up sand bars. They occupy many times the area they would if straight, and practically ruin the soil which is worked over by the water. (Mud Lick Farm, Julian, Center Co., Pa.)

There is another feature of the matter that ordinarily is overlooked. This is the black eye which the farm is given by a ragged-looking piece of swamp land touching the clean acres. Whether the farm is on the market or is to be kept as a home, the waste lands cut down its value and damage its reputation among all who see it, including the stranger passing by, the neighbors over the fences and the man who lives on it.

It is a well-known fact that malaria disappears when mosquito bites are eliminated, and that the mosquitoes can be eliminated by draining the swamps.

The excavation done by a single line of charges of explosive properly placed in watersoaked clay soil is remarkable. The ditch resulting sometimes is two-thirds as deep as it is wide at the top. The bottom is U-shaped.
In the lowland sections of the country this has been done with great success. Even in the flat lands joining the ocean where tide water sometimes washes in over land and makes ponds, the opening out of channels has drained away the water and killed off the mosquitoes.

Other enemies that breed and lurk in swamps are weeds and predatory animals. The seed weeds in the swamps pollute all the surrounding land, and the cleaning up of the swamp is a favor and a benefit to the entire neighborhood.

Horses and cattle often get mired into the soft mud and are unable to get out without help. They may stick there and starve if not discovered and pulled out, or they may break a leg, or sprain themselves in their struggles.

One of the meanest things a farmer has to do is to haul loads of hay, grain, manure or fertilizer through a swampy place in the field. The remedy is to open a ditch through the center, after which the soft ground will harden up and the ditch can be bridged.

But not all wet land should be or can be drained. In general whether it will pay to drain or not will depend on how cheaply the job can be done, though this is such an indefinite rule that it is not of much value. Many a drainage job that can be done for $50 to $75 will add $100 to $200 to the value of a property. From a financial standpoint, a man is not justified in spending more money than the crops that can be grown will return in a reasonable number of years, though other considerations may make it wise to spend more.

The Essentials of Successful Ditching

It is well to have a clear idea of what to require of a ditch before attempting to complete the plans for it.

The successful drainage ditch should be straight, to give an even, swift flow of water without cutting out the banks or filling up the bottom. Its sides and bottom should be smooth and true, both to facilitate the flow and for appearance. It must be deep enough to put the water-table at a proper level. It must be wide enough to give the capacity required by the volume of water to be carried in flood times. The grade, of course, must be enough to carry the water away and to make the drainage action sure.

The excavated material ought to be well scattered and spread evenly over the surrounding land, without leaving a ridge or dyke along the sides of the ditch. When this material is piled up along the ditch it takes up ground space and acts as a dam for surface water and compacts the subsoil beneath by its weight, making the drainage of the fields much slower. Finally,
the ditch in respect to cost, time and men needed for construction, must come within the available limits. The cost must be low, the time of construction short, the men required few, and the work not unreasonably hard. Frequently if the ditching is to be done at all it must be by only two or three men in what practically amounts to spare time.

Nature of the Ground

The reasons why land is wet are few. There may be a layer of ground a few inches or a few feet under the surface, holding the water from escaping downward. The topsoil itself may be of such a nature as to prevent water from percolating through it. The water may keep rising from springs, producing the condition called seepage or spouty land. Again, the water-table, or height of the surface of a nearby large stream or lake or bay, may be nearly up to the surface of the ground, or the stream or ditch carrying away the water may be too small or too high at its mouth.

The nature of the ground must be considered in deciding on the method of ditching. Sand, for instance, is easiest to handle by some methods, and hardest by others. Dry ground handles cheapest in some ways and most expensively in others. In ditching you are likely to encounter hardpan, gravel of all sizes, both loose and in solid beds, and every kind of mixture of these materials. Each of these conditions calls for its own sort of treatment.
A ditch blasted through very dry ground without any side cutting. The result is not altogether a success, since the excavation is reduced in amount and is incomplete, and the cost is high. The soil is coarse sandy loam with much clay beneath. The blasting would have been much more successful if the ground had been full of water and the sides of the ditch cut before the blasting was done. (Near Snow Hill, Md.)

Heavy charging and skillful management will blast out a very good ditch through extremely difficult ground. Here the soil was matted with green roots. Some of them are left projecting into the ditch, but most of them are broken off and thrown out. The excavation of earth was very complete, owing to its watersoaked condition. (Georgia.)
Choosing a Method of Draining

The methods that are available for making ditches are:

Shoveling by hand,
Plowing,
Trenching with machine equipped for excavating,
Blasting.

Each method has its place. In choosing a method many considerations enter into a wise decision. The purpose for which the ditch is made—whether open ditch or underdrain, canal for water or boats, and the like, must determine the character of the ditch. The kind of soil, the size of the ditch, the amount and kind of obstructions, the time available before the job must be finished, the men that can be put on the job, the capital available for labor and equipment, the source of the water to be drained away, the height of the water-table, the use of the land to be drained, the amount of water to be carried and the fall of the land—all these factors have a bearing on the selection of the method of making a ditch.

Tile Drains

No open ditch through cultivated land should be considered when conditions are such as to make underdrains better, and when money is available for constructing them.

But in a great many places the nature of the ground or water flow is such as to require open ditches. In other places they are just as good as closed drains. For instance, through pasture land and woods an open ditch will do just as well as an underdrain and better where there is a spring or brook which overflows at times. In muck land closed drains are not practicable.

Ditches for immediate laying of tile cannot be blasted out with satisfaction; the bottoms are left too soft to hold the pipe properly. If funds for tile draining are not available immediately, an open ditch can be made by blasting which, after a couple of years, will be entirely satisfactory for tiling, though

Note the projecting knobs of earth held by matted roots of trees and brush. Such irregularities in the sides of a ditch are not a disadvantage except in appearance in a ditch where the flow of water is heavy and swift. But when the volume of water is small and the fall slight the edges should be smooth and straight.
Proper blasting will open a channel through thick brush and grass, though such a ditch will not measure nearly so much in the clear as though the land was clean and free from roots. You can blast channels for boats or for drainage through a marsh where the ground is under water. (Kentucky.)

the earth required to refill the ditch will be scattered widely. Light blasting very often is desirable, however, to loosen hard ground in order to make digging of tile ditches by other methods easier.

**Open Ditches**

Large ditches and canals, 15 feet wide or more, and miles in length, often justify the use of a floating dredge. Those who are interested in methods of trenching for underdrains, and in excavating machinery, floating dredges, ditching plows and the like, should get Farmers' Bulletin 698 of the U. S. Department of Agriculture. It goes into the subject in detail.
When many stones, roots and stumps are present, a dredge, or in fact any excavating machinery, cannot be used to advantage or at all. Ditches less than 2 feet deep can be plowed out cheaply, using two or four horses hitched by means of a chain to a plow of some kind. Another implement that is effective for making very shallow ditches is a scraper, either with or without wheels. A road machine or scraper is about as good as any. The trouble with these machines is that they will work little more than to a depth of a foot, and are expensive. Their advantages are that they scrape the dirt well back from the edge of the ditches and make an even, clean-looking job by machinery instead of by hand.

When tile is to be laid in hand-dug trenches, begin the spade work in the bottom of a plow furrow. By running the plow twice in the same place you can make the furrow nearly 12 inches deep.

Blasting of ditches is discussed under a separate heading.

Possibilities and Limits of Blasting

The blasting method can be used for making almost any open ditches. A blasted ditch made with one line of charges usually is about twice as wide
at the top as it is deep. The sides and bottom are fairly even. The dirt is spread out widely without leaving ridges down the sides. Ditches can be blasted successfully in clay, loams, gravel, thick muck, peat, and, in fact, every sort of earth except very thin muck and dry sand. Ditches can be blasted through sand when saturated with water.

It is easier to state the limitations of the blasting method than its possibilities. As stated above, you cannot blast ditches through dry sand. Thin muck runs into the excavated channels. In any ground where there are many roots of trees or brush, the sides of the blasted ditch will be ragged unless the roots are cut beforehand along the sides. In blasting through heavy sod, the sod sometimes folds back without tearing loose, or else simply flops back down into the ditch—unless the edges are cut before the blast.

These are the limitations of blasting, and there is a way to overcome each of them except that of thin muck. The fact is that the way explosives will cut out a narrow channel is really wonderful. Those who have not seen the blasting of a ditch can have no idea of the efficiency of the work of explosives for this purpose or of the clean and finished job they do.

Explosives work to the best advantage when the ground is wet— in fact in thin mud. It takes less explosive to throw out a required sized ditch, or the same amount of explosive will make a bigger ditch, when the ground is thoroughly wet than when it is only damp or is dry. The blasting may be done with perfect satisfaction through ground that is so soft that there is no footing for horses and no support for wheels. In fact, it can be done when the surface of the ground is under water.

Excessively soft ground, stones, stumps and roots are the things that make ditching by hand or by machinery costly and difficult, if not impossible. But they interfere with blasting very little and raise the cost only slightly. Blasting of ditches can be done in dry ground of a heavy nature. The general rule is that the wetter the soil, down to the thin muck stage, the better and cheaper the blasted ditch.
It is possible to blast out a good ditch through almost pure sand, as this ditch shows, provided the ground is full of water and the operator understands his business well.

About the smallest ditch it is worth while to blast is 1½ feet deep and 3½ feet wide. From this size up to 6 or 8 feet deep and 18 or more feet wide the use of explosives has advantages over almost any other method under favorable conditions. But in general the efficiency of the blasting method falls off after the depth is greater than 6 feet and the width greater than 18 feet. For long ditches a floating dredge will be economical. Small ponds may be dug by blasting.

In blasting ditches two or three men can do the work of a great many. They can accomplish in a day or two what would take them months to do by hand.

**Laying Out the Ditch**

The size or capacity of ditch required, the grades, the depth and the lines should receive careful attention. When there is considerable length of ditch or considerable acreage to be drained it is wise to employ a drainage engineer or a professional surveyor in getting the grades and in determining capacity. Except in very large operations the matter of depth and location of the lines of drains is largely one for farmers themselves to decide, because they know the requirements of the different soils and of farm operations, as well as having had the chance of observing the flow of flood water.

The eye is not to be depended on in determining the fall of a piece of land that is nearly flat. Use a level. One way of using it is to drive a post at the upper side and fasten to this, by nailing or bolting, a crosspiece with a straight edge up. Then lay a level on the straight edge and make it absolutely level. The crosspiece should point directly toward the lower side of the piece of land.
In big drainage projects where large canals must be made the blasting method often proves economical. There is no doubt that explosives will do the excavating, as this picture shows. Labor cost and complications are reduced to a minimum on account of the few men and short time required for the blasting.

to be drained, where a helper must stand, holding a marker which he raises or lowers on a pole. Sight over the straight edge and have him elevate the marker till it is on a true level with your crosspiece. The difference between your distance down to normal ground surface or normal water surface, and his, will be the fall.

This ditch is a good instance of the speed and efficiency of the blasting of ditches. Three men made it complete, as the picture shows—1000 feet long—in 5 days. About 400 pounds of explosive was used. Much cutting of roots and sod was required. (The Hart E. Hutchens Co., New Brita'n, Conn.)
An "A" frame or any other support for the level will do if it will hold the level steady. Sights for attaching to the level can be bought of almost any hardware store. They are as accurate as rifle sights. Tripods for holding the level also are made and can be had at most hardware stores. The plain level is not very accurate. If you do not use sights, repeat the sighting two or three times to make certain of the finding.

A fall of one inch to each hundred feet is enough to carry off excess water from a field in most cases. This is for straight ditches. If the ditch line is to swing here and there, an inch of fall is hardly a sufficient allowance.

The appearance of grade is deceiving. Few pieces of ground are so flat they cannot be drained. Watch the land when it is flooded and the water is going down. Set some stakes then to indicate its level and its channels. If a small stream flows through the land, the line of sight should not follow its wandering course. The total fall should be determined from just two positions—one where the stream enters and one where it leaves.

The flow of the flood water is a good guide in locating the proper line for a ditch. This is the natural line of drainage. If nothing else interferes, place the ditch in this position. The idea is to have it as near as possible to a straight line and as short as possible. But avoid cutting fields with open ditches when possible.

The one important factor to consider in determining how deep a ditch should be is the proper height of the water-table in the ground. This is the level of the water that will stand in a well or hole dug in the wettest part of the field. The water should be at least 4 or 5 feet below the surface in ordinary heavy loam or clay, and 1 to 1 1/2 feet in muck.

The deeper a ditch is the farther and more thoroughly it will drain land. Your calculations as to how far you can rely on one ditch to gather water and to effect the drainage of ground must be based on this matter of the depth of the ditch. The nature of the ground has a good deal to do with it, particularly with the rapidity of the drainage. A loose, open gravel will drain out nicely in a few days, and a tight stiff clay will take weeks. Naturally the ditches should be closer together in the clay than in the gravel. Other soils can be judged from these.

The depth must not be more than the water-level at the mouth of the
The first shot (of 12 charges) of a ditching operation. Note particularly how abrupt and clean-cut the end is. The last charge lifted its load fully and cleaned out the ditch in good shape. The next one placed beyond will continue the excavation just as well. (Mud Lick Farm, Julian, Center Co., Pa.)

The first shot (of 12 charges) of a ditching operation. Note particularly how abrupt and clean-cut the end is. The last charge lifted its load fully and cleaned out the ditch in good shape. The next one placed beyond will continue the excavation just as well. (Mud Lick Farm, Julian, Center Co., Pa.)

ditch or drain. This is a governing factor in many places. When a ditch empties in a stream you often can carry the channel farther down and secure a lower level if it is needed; or the stream itself may be deepened.

The water carrying capacity of a ditch is most largely governed by its width. Often then narrowest ditch that can be made will have more capacity than is needed to carry all the water there is. The bottom should not be wide, but should be narrow, almost like a broad V, because the amount of water to be carried at low water stage is small and it should be confined closer to make it flow better. In flood times the water will rise higher and will make a broader stream.

Determining Width of Ditch

Where large swamps are to be drained, or the flow from larger springs is to be carried away, a ditch of minimum width sometimes is not big enough. If you can calculate the volume of water to be carried away, you then can figure the correct width for your ditch. Measure the flow per minute in cubic feet at some outlet. Or measure the amount of standing water by
getting its depth and extent. Provide ditch enough to pass the volume present in the required time. In any case the ditch should be big enough to clear away the water of a 2 or 3 days' rain shortly after it stops coming down, and to take care of spring floods.

How to Make Ditches by Blasting

Ditches are blasted by loading suitable charges in holes made in a row or line. Each charge of explosive properly placed for ditch blasting will blow out, roughly stated, a crater which is half to three-quarters as deep as it is wide. Nearly all the dirt is thrown out. Most of it is lifted to a height of about 200 feet in the air, requiring some seconds before it returns to the ground.

The sides and bottom of blasted ditches have 6 to 12 inches of loose dirt, which can be left where it is if the ditch is big enough in the clear, or can be taken out easily and cheaply by shoveling or

In these ditches the excavation of earth was satisfactory, but the number of roots was so great that the result as a whole is not what it should be. No side-cutting was done before blasting. If there had been, the resulting ditch would have been smooth, straight and deep. In blasting through brush and timber, the long, sharp shovel blade, the hay-knife and the axe are necessary tools. (S. Chester Coursey, Hayden, Md.)
with light horse scrapers if a larger ditch is wanted. Good blasting practice will so load the charges that the ditch as cleaned out by the blast will be big enough in the clear and will require very little, if any, hand finishing.

**Firing Charges**

One of the first things that must be considered when planning to make a ditch by blasting is the method of firing the charges of explosive. Most of the rest of the operation hinges on the firing so much that this matter must be determined before even buying the explosive.

The standard practice is to fire all charges electrically, as will be described immediately following. This method is sure in results under any conditions. Ordinary cap-and-fuse firing cannot be used successfully in ditching, except by the transmitted detonation method in which the center charge only is set off by a cap, the rest being fired by shock transmitted through the ground. This method is fully explained on pages 89 to 92.

**General Method of Firing**

Ditches can be blasted through any sort of ground except dry sand when the charges are fired in this way. The procedure is as follows:

The charges are prepared for loading, with electric blasting caps, in the manner described on pages 150 and 151. Prime each charge. Holes are made in the ground on the ditch line and the charges are loaded as described in following pages.

The holes or charges should be spaced 30 to 40 inches, and where very heavy charges are used, as much as 50 or 60 inches apart. They must be close enough together so that all the earth between each two will be thrown out clean, leaving no ridges in the bottom of ditch. Thirty inches ought to be close enough under any conditions of soil and size of charge. The only way of determining definitely just how far apart the charges should be is to make test shots, as suggested on page 98, in the discussion of amount of explosive required for charges. As many charges should be loaded as your electric current can fire.

The actual firing is done by connecting the wires of all the charges and sending an electric current through them. An electric blasting machine should be used to supply current, though power or light current can be used. A full discussion of the details of how to connect wires and to fire, is contained in the special chapter on the subject in the latter part of this bulletin.

You can fire as many charges as your blasting machine will handle. The machines are made in different sizes, to fire 3 to 150 charges at once. Procure a large machine if you have miles of ditch to blast, but if you have only a few hundred yards, a 30-charge machine is big enough.
The proper explosive for blasting ditches by this method depends somewhat on the soil. In all clay and heavy soils use 20% ammonia dynamite, and for large ditches use 30% or 40% ammonia dynamite except when the work is under water. (See page 154.) In blasting ditches in wet sand or other light ground use 50% nitroglycerin dynamite. Where charges must remain under water more than half an hour, use nitroglycerin explosives only, for ammonia explosives will deteriorate if soaked for excessive periods of time. It is well to use a low-freezing grade of the explosive at any time of the year, since this guards against chilling, and insures a more thorough detonation of the explosive by the blasting cap.

Electric blasting caps, connecting wire, leading wire and blasting machine with the other tools needed for loading, are the supplies demanded for ditch blasting by this method.

Depth for holes, amount of explosives per charge and many other details of the loading are discussed on pages 95 and 97.

Transmitted Firing

When the ditch is to be blasted through ground that is saturated with water, the method of transmitted firing often can be used to advantage. In order to insure its complete and unquestioned success, the water must cover the charges and had better rise in the holes nearly to the surface of the ground.

Under such conditions transmitted detonation can be expected to succeed even in sandy ground and gravel. It is in muck and clay fully saturated with water that the method is most successful.

Transmitted firing is made possible by the fact that high explosives can be fired by shock (as by that given by a cap, for instance). Under the conditions of soil described above and of proper loading, the shock of the explosion of one charge will travel through the ground and water with enough force to fire the next charge, and so on down the line. So rapidly does this take place that in a line of charges hundreds of feet long you cannot see any difference in time between the middle and end explosions.

If cartridges of explosive are laid on a plank a foot apart and one of them is fired with a cap and fuse or otherwise, the others likely will be exploded by the influence projected through the air. In actual ditching work the shock of one
charge cannot be depended on to travel through the ground strongly enough to bring about full and complete detonation more than a couple of feet.

The usual distance apart that is best for charges to be fired by transmitted detonation is 15 to 20 inches. The exact distance in any particular soil at any time must be determined by test shots. Try a shot of 8 or 10 charges (of the amount of dynamite and at the depth of loading required, as explained on pages 97 and 98, spaced 12, 15, 18, 20, 22, and 26 inches apart.

Careful observation of the blast resulting will show the point beyond which charges fail to explode or explode weakly. The correct spacing of charges, to insure full detonation, will be about two-thirds of this limit.

Spacing of Charges

One charge may fire another at a greater distance than is economical, because it merely may explode it weakly, without developing anything like the full force and speed. And on top of that, each weaker explosion sends a still weaker one on to the next charge, till a point is reached a few charges away where the shock transmitted is not enough to bring about firing at all.

This weakening of the transmitted shock is important, because the strength of an explosion of dynamite depends on the severity of the shock which fires it. For illustration, and not that these figures bear any relation to the true amount of force, if the first charge, the one fired with a cap, gives off 10 pounds of energy in the form of a shock, and this 10 pounds is diminished to 8 pounds by the time it reaches the next charge, this second charge will not detonate with quite 10 pounds of shock energy. It may have only 9 or 8. And in turn, the shock energy from it will be diminished to 6 or 7 on reaching the third charge. If the particular kind of explosive used requires a full 6 pounds of shock to detonate it completely, the transmitted method of firing is going to fail. Even of those charges which do explode, half will give much less than their full force.

Water is not elastic, but air is, and dry soil is and absorbs shock because it contains a good deal of air. The gases of an explosion drive water-soaked

When roots and sod are not cut along the sides of the ditch before the blasting, the edges are never as smooth and as straight as with cutting. An effort was made to trim this ditch up after the blast. It carries water about as well, but it doesn't look to be as good. (In Miller Drainage District, Marion Co., Oregon.)
ground as a steel rod can be driven by a hammer. In it there is but little "give," hence the shock travels with a minimum of loss in force. In dry ground the air cushions the blow of the gases and eases them to a standstill within a short distance. Clay is more solid than sand, and this explains why transmitted detonation works better in heavy soils than in light ones.

The nature of the ground and the amount of water present therefore largely govern the spacing of charges, though a large charge of course will throw a shock slightly farther than a small one.

As will be seen from foregoing named facts, the effects of lack of water and of light, spongy or sandy ground, can be counteracted somewhat by setting charges closer together. When necessary it is practicable to put them only a foot apart. To put them closer, however, is not practicable, for it costs too much. On the other hand, when the charges are heavier than ordinary—say of two cartridges or more—in wet, heavy ground, they may be spaced up to 26 inches apart with satisfaction.

Temperature influences transmitted detonation only by reason of the fact that explosives are less sensitive to shock, and harder to fire when cold than when warm. All grades explode easiest when at a temperature of 70 to 80 degrees. Straight nitroglycerin dynamite must be used at a temperature of higher than 50 degrees.

**Temperature of Ground**

It is not well, for many reasons, to attempt to fire too many charges at once. Several hundred can be fired successfully sometimes, but the usual limit had better be 50 to 60.

When the nature of the ground, amount of water present or temperature are not of the best for securing transmitted detonation, matters may sometimes be helped by taking advantage of the fact that blasting caps are much more sensitive to shock than the explosive itself. Place a common blasting cap, without a fuse, but with the open end filled with tallow, every 25 to 50 feet. These caps may help to restore the diminished force of explosion, making satisfactory detonation extend much farther than it would without them.

A ditch 10 feet wide and 5 feet deep through newly cleared land. The extra width of the excavation helped to tear entirely loose and throw out stumps and roots, leaving the edges comparatively clean of projecting roots. Under such conditions finishing the ditch after blasting is better than to try to cut the edges before. (Paragould, Ark.)
Stones, roots and old logs interfere with transmitted detonation. When these are located in the line of the ditch it is necessary to fire charges on both sides of them as at the beginning. Pay careful attention to changes in soil as you work along the ditch line. It may be necessary to shorten the spacing, or, again, it may be possible to lengthen it and save money.

The firing of the line of charges by the transmitted detonation method is done by loading the required number of charges without priming or with caps and no fuse as described above, all except the center charge of the row. In it place a double charge of explosive, or at least an extra cartridge of explosive, primed with cap and fuse or with electric blasting cap. Fire this charge in the usual way.

Prime Center Charge

Sometimes an electric blasting cap placed at each end as well as at the middle of the line will fire difficult charges successfully. Once in a while the electric blasting caps may be needed even closer—say every 3 to 5 charges.

The proper explosive for transmitted firing ditch blasting is nitroglycerin dynamite of 50% strength—either regular or low-freezing. The 20% strength dynamites recommended for electrical firing cannot be used at all under this method, because they are not sensitive enough.

**Summary of Firing Facts**

Transmitted firing requires only the explosive itself, and a cap and some fuse for each couple of hundred feet of ditch, while electrical firing requires wiring, an electric blasting cap for each charge and a blasting machine or other source of current. This advantage of the former method very often is offset, however, by the fact that it requires nearly twice as many holes as electric firing. It is easier to load two cartridges in one hole than to make two holes. In addition, electric firing always can be depended on for the desired results, while transmitted firing will succeed only when the ground is full of water. As for quantity of explosive required by each method to excavate any certain ditch where either can be used: In theory the two methods require about the same. In practice, however, more will be used in transmitted firing, unless the work is done very skillfully. The saving in the use of this method comes largely from a saving of electric blasting caps and time, and the need for little equipment.

**Preparation of Ground and Loading**

During the early days of ditch blasting, before experiments had standardized practices, much objection was taken to the ragged edges of ditches blasted through sod and through brush and woods. The sod would not tear loose and fly away from the ditch. It would either fold back and make a ridge along the ditch, or it would flop back into the ditch after the dirt beneath had blown out. The remedy is to cut the sod and roots along the edges of ditch before blasting.

Cutting Roots and Sod

When there is sod, two furrows should be plowed along the ditch line—one at each edge. Another plan is to cut along the sides of the ditch-to-be with a spade, axe or hay knife. In case the line of the ditch runs past trees, or through brush or forest land, the roots should be cut on both sides the ditch. An axe is needed for the big roots. Where there are many roots the ground should be cut 18 inches deep.

Make the cut at the angle the side of the ditch should have, say about 45 degrees. The blast will clean out the dirt to the cuts and will leave the wall on the outside firm and intact. Cutting the edges of the ditch saves trouble...
and work after blasting. It insures that the sides and edges of the ditch will be as straight as though the ditch was shoveled by hand or plowed. But it should not be understood that ditches cannot be blasted without cutting the ground. Except through extremely heavy sod and roots, explosives used alone will clean out good channels when loading and firing are done properly. The cutting of the edges simply makes a smoother, more complete job.

The charges should be placed along the center line of the proposed ditch, except where the ground is harder, or higher at one side than at the other, when they should be placed 6 to 12 inches from the center toward that side. The eye is not capable of keeping the line of charges true. Stretch a string where they should go. In making the holes the man should have a measuring stick to space them accurately. Guesswork on this point is likely to be expensive. Make the holes straight down into the ground.

Locating Line For Holes

It is much easier to make holes in soggy ground than in dry ground. In fact, it is almost impossible to sledge down a bar in some dry ground. When there are no stones, a soil auger often is of advantage, though the bar and sledge are hard to beat for speed and results. Modification of the up-and-down position of the cartridges or charges is desirable only when you are deepening ditches already made, with bottoms of thin mud or thick muck. In such material you need punch no holes. Just push the cartridges into place down in the mud with your hand and place them in a horizontal position lengthways of the ditch.
If you have a windy day for the blasting, with the air drawing strongly across the line of the ditch, you will be surprised to see how far the falling dirt will be carried away from the ditch during the few seconds it is in the air. On a quiet day, 6 to 12 inches of dirt will fall back into the ditch. On a windy day your finished ditch will be several inches deeper and wider than on a calm day. Do not take from this that a windy day is demanded for satisfactory results. The force of the blast spreads and scatters all but a little of the dirt. The wind merely helps.

When water covers the charges, be sure to make the primed cartridges, and the cap and fuse, waterproof with tallow or paraffine at points where they join. Tar and thin lubricating grease are very poor materials for waterproofing.

When water covers the charges you should arrange to load them and to fire them quickly. A good plan is to make all the holes for one section, then prepare the charges, as to priming and waterproofing and distributing them along the line. Quickly test each hole for fallen stones, caved-in dirt, and push the charges to the bottoms of the holes. It is best to limit their soaking to a half hour. The explosive is likely to weaken if left too long.

If the holes cave in soon after the bar is withdrawn, do not attempt to load and blast long sections at a time. In loose gravel and sand, especially where water covers the surface or nearly so, you will have trouble getting the charges down to the bottoms of holes. The best plan is to get a tin tube about 1½ inches in diameter and sink it in the hole over the bar. The explosive then can be loaded without trouble when the bar is withdrawn.

Generally speaking, a ditch charge should be tamped slightly. The more tamping you use the broader your ditch will be in proportion to its depth. If you want a narrow ditch you must let the gases rip their way upward easily. In dry or damp ground, fill the hole about half full and tamp well. When water rises high in the hole, use no tamping at all, except to tramp shut the upper 6 inches.

The ground had better be warm for ditch blasting. If it is cold you must load and fire the charges quickly, to prevent chilling of the explosive. A light
crust of frozen ground makes little difference when charges are handled properly; more than \( \frac{1}{4} \) to \( \frac{1}{2} \) inch will interfere seriously.

**Regulating Depth and Width**

The dirt will clean out 6 to 8 inches deeper than the bottom end of the charges when conditions are normal. Explosives work more efficiently in ditch blasting when they are placed as shallow as possible. When the holes are too deep an excessive amount of explosive is required. A layer of hardpan or cemented gravel in the ground to be removed requires slightly deeper placing than soft ground. The rule for the usual job is to place the charges within 6 inches of the bottom depth desired, and for large ditches and heavy charges within 10 or 12 inches of the desired depth. The exact depth may be ascertained by trial shots.

The greatest depth it is practicable to blast at one shot is about 6 feet. If a deeper ditch is wanted, blast a second time in the bottom of the first excavation. (See table on page 98 for depths for charges.) The blasting out of very large canals should proceed along these lines. They involve no principles not explained for the making of small ditches.

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A channel 35 feet wide and 6 feet deep that was excavated by blasting. The water has smoothed the sides a little, but in the main the big ditch looks in the picture as it looked after the blast which opened it. The cost of such ditching can be figured accurately in advance when dimensions are known, the kind of soil and its condition considered, and the cost of explosions at hand. (Athens, Ga.)

One line or row of charges frequently will make a ditch up to 10 feet wide and 6 feet deep. To make wider ditches use 2 or more rows.

Usually 2 rows of charges will be needed for ditches between 8 and 12 feet wide if less than 4 to 6 feet deep, and 3 rows for ditches 12 to 18 feet wide.

**Wide Ditches**

The lines or rows of charges should be placed about 4 feet apart, except where the charges consist of more than 4 cartridges and are close together in the rows on account of transmitted detonation, when the rows may be as much as 6 feet apart. In blasting out very wide and shallow ditches or canals, it sometimes is of advantage to load 2 rows with light charges rather than to attempt to blast out
How to deepen a ditch by a second blast in the bottom of a first excavation.

Three-row ditch loading—See page 28.

Two-row ditch blast loading.

Half cartridge loading for very small ditch.

Single-row loading for large ditch—if larger ones are needed, more rows of charges.
the ditch to the required width with one row heavily loaded. The heavy charges might dig deeper than required. (See table on page 98.)

Invariably all the rows should be fired together. This, of course, is accomplished when the electric method of firing is used. When using the transmitted detonation method, put in extra charges between the rows at the center charges, and then fire one—usually the center charge of the middle row—with a cap and fuse. All these center charges and extra charges should be heavier than usual. Put in an extra cartridge, at least. A still better way with transmitted detonation is to fire the center charges of all the rows together electrically.

A pond excavated entirely by blasting. Several rows of charges were loaded and fired simultaneously. The wind carried the earth to one side, forcing it to fall on adjoining ground instead of back into the hole blown out. (H. E. Ellis, Ashland, N. J.)

Amount of Explosive Required

Before giving tables of the average amount of explosive required for various sized ditches, it is well to describe a few typical examples of ditches that have been blasted, of which records were kept.

In a clay soil, with water rising almost to the surface of the ground in the holes punched for charges, charges of one cartridge of straight nitroglycerin explosive placed 18 inches apart and 30 inches deep blew out a ditch 4 feet deep, 3 feet wide at the bottom and 7 feet wide at the top.

In a similar soil, with less gravel, charges of one-half cartridge of straight nitroglycerin explosive placed 15 inches apart and 18 inches deep made a ditch 2½ feet deep and 5 feet wide. At another point in the same field, on the same day, charges of 2 cartridges (one pound of same explosive), placed 30 inches deep and 24 inches apart, made a ditch 9 feet wide and 4 feet deep.

In loam ground, too dry for successful transmitted detonation but still somewhat damp, charges of 2½ cartridges placed 2½ feet deep and 3 feet apart, and fired electrically, cut a ditch 4 feet deep, 8 feet wide at the top and 2 feet wide at the bottom.

Through a thicket with brush and small trees measuring 1 to 3 inches in diameter, in heavy pure loam well soaked with water, charges of 2 cartridges of
straight nitroglycerin dynamite placed 22 inches apart and 3 to 3½ feet deep made a ditch 4 feet wide at the bottom. The ditch was loaded too heavy. Charges of 1½ cartridges would have been better.

In very wet and miry clay, a ditch 20 feet wide at the top, 12 feet wide at the bottom and 6 feet deep was blasted with 3 rows of charges of straight nitroglycerin explosive. All the charges were spaced 20 inches apart in the rows. The charges in the middle row were 1½ to 1¾ cartridges, varying a little on account of variations in the soil along the ditch. In the two outside rows the charges were one cartridge each. The rows were placed 4 feet apart. One section of the same ditch was cut out to a depth of nearly 8 feet by using 1½ cartridges to the charge in the 2 outside rows, and 3 cartridges to the charge in the middle row.

When the ground is fairly heavy and is full of water you can count on each pound of explosive properly placed to clean out 1½ to 2 cubic yards of earth. The variations from this rule, both ways, will be on account of the presence or absence of water, the nature of the soil and the size of the ditch. A ditch made with a single line of charges (measuring, usually, 3 to 4 feet deep by 3 feet wide at bottom and 6 to 7 feet wide at top), will give the highest efficiency, and when the conditions are very favorable will show even a little more than 2 cubic yards per pound of explosive used.

As the amount of excavation in one body increases, the efficiency of each pound of explosive will fall off somewhat. In very large ditches that are wet you will get out only 1½ cubic yards per pound of powder. In dry ground blasting, particularly if the ground is light, 1¼ or even one cubic yard per pound will be the average.

| Number of Half-Pound Cartridges of Explosive Required per Charge for Blasting Ditches |
|-----------------------------------------------|-----------------------------|
| **Depth of Ditch** | **Depth of Hole** | **Amount Charge Transmitting Detonating** | **Amount Charge Electric Firing** |
| 2 ft. | 1½ ft. | ½ cartridge | ½ cartridge |
| 2½ ft. | 2 ft. | ¾ cartridge | 1 cartridge |
| 3 ft. | 2½ ft. | 1 cartridge | 1¼ cartridges |
| 4 ft. | 3½ ft. | 1½ cartridges | 2½ cartridges |
| 5 ft. | 4½ ft. | 2 cartridges | 3½ cartridges |
| 6 ft. | 5 ft. | 2½ cartridges | 5 cartridges |

The width of the ditch can be calculated by doubling the figure for the depth in case of a single row of charges, or in the case of more than one row, by adding to the figure for double the depth the distance between the rows of charges.

The table given above is correct for average conditions. Since variations in soils, temperature and other factors make necessary varying loading, the figures here should be used as a guide for starting test shots.

No ditches should be blasted without testing the loading thoroughly before proceeding with much work. Blast small sections at a time, and vary the loading to suit the changes in the nature and condition of the ground you encounter along the ditch line. Clay, sand, muck, loam and gravel all require variations in depth of charge, amount of explosive and sometimes in spacing of charges. Proper tests will enable you to decrease the cost and to make a better ditch than otherwise would be possible.
Typical test loading to determine proper charges and placing of explosives for electrical firing. Note the variations in spacing between holes as well as in amount of explosives used. (See page 90.)

Five to ten holes make a good test. This should be repeated several times. Vary the depth and spacing and the amount of charges. Remember that proper blasting will make perfect ditches at low cost, and that the only final way of determining proper loading is to try it. Well-balanced charges will be so loaded and spaced that the gases will lift the full load of dirt without overlapping much and without skipping any ground between. Load just heavy enough to insure clean excavation without excessively high throwing of dirt.

Making 3-foot holes in clay and gravel, preparing charges, loading and firing can be done by one man at the rate of 20 to 50 charges per hour. If there are many stones in the ground, or if the ground is hard, the work will go more slowly. Wet gravel makes slow work. Two or more men will get more done in proportion than one man. Under favorable conditions one man has blasted out 1,000 feet of ditch 3 feet deep in 12 hours. One man should be able to blast 350 to 450 feet of ditch per day through brushy ground; if the land is clean he can do more, though where ground is so dry as to cause trouble in making holes, the work will go slowly.

A crew of ten men—eight laborers, one blaster and a boss—working at a big ditch. The employment of so many men is not justified except for very long ditches, for the job lasts only a day or two. A good sized crew enables the blaster to place and to fire the charges quickly, which is an advantage when the holes fill with water and when the temperature is low. (Max Östner, Diehlstadt, Mo.)
Ditch blasters should have a soil auger, two crowbars, a sledge, a couple of long-handled shovels and a cutting spade. One of the bars should be 4 or 5 feet long and should be constructed for driving. The other should be 6 or 7 feet long, and may be made of piping, with a solid sharp steel point welded in. It is for use as a churn drill, without sledging. A broomstick or a wooden rod about 1 1/2 inches in diameter, for pushing the charges down and tamping, and an axe to help cut roots, also are handy. Of course, boxes or baskets for carrying explosives, cap crimpers and the usual outfit for handling and loading explosives as described on pages 36 and 37, will be required.

**Incidentals**

Large stumps, stones or other obstructions along in the line of the ditch require a little extra explosive. Stumps up to 6 inches through and boulders up to 18 inches in diameter will be thrown out by the regular ditch charges. Above these sizes use extra loading, as follows: For each 6 inches of the diameter, use one cartridge of explosive. For stumps larger than 30 inches, use 3 to 4 cartridges for each foot of diameter. Put the extra explosive directly under the stump or stone.
Through heavy sod, as shown here, blasting cuts the sides somewhat irregularly unless the grass roots are first sliced with a shovel blade or hay-knife. This ditch is well opened and entirely successful, but a good many projecting chunks of sod are left sticking from the sides.

Ditches blasted through ground that has a raw surface and no roots will require no finishing afterwards. The edges and sides should be fairly true and even and the dirt should be well scattered. There will be few or no ridges along the ditch. Even through sodded ground and through woods and brush, when the sides of the ditch have been cut before blasting, there will be little hand work needed. If no preparatory cutting is done, however, some shoveling to smooth the sides and some cutting to take out projecting roots and sod may be advisable.

This ditch was blasted out on a still day, and most of the dirt fell straight back to the ground. But it was spread out so that only a little of it fell in the ditch. The few roots projecting into the excavation can be cut off with little trouble. It is the roots of sod and matted roots of smaller brush and trees which give the trouble in blasting and require cutting beforehand. (Robert Jemison, Birmingham, Ala.)
This work should be done right after the blast, before the water has a chance to compact the sides. If necessary, leave dams of unblasted sections 3 or 4 feet long every few hundred feet in the ditch, to hold back the water long enough for finishing. They can be blasted out afterwards. An old axe or a sharp grubbing hoe or adz will cut the ends of roots easily. But all this work can be avoided and a better ditch result if you will do the cutting before the blasting. Large clods, pieces of stumps or roots and stones in the ditch channel after blasting should be thrown out without delay.

It has been stated (page 79) that ditches for tile or pipe cannot be blasted out satisfactorily. The dirt can be loosened with light charges, however, and the shoveling or excavating by other means thereby made much easier. If the pipe is to be placed deeper than 4 feet, it is even practicable to blast a 3-foot or deeper ditch on top, leaving only a little more excavating to do in the bottom. One must bear in mind, however, that the blasting throws dirt too far away to be shoveled into cover piping. Loosening as explained above, however, to make digging easier, does not throw the dirt away.

![Two post electric blasting machine—push down type.](image)
Blasting Orchard Soil

The blasting of soil for tillage purposes was first tried more than a generation ago. Since 1900 the practice has become general in many sections of the country, particularly in those localities where orcharding is one of the main businesses.

The experiences of individuals and of official investigators have not been uniformly successful, though some remarkable results have been secured. When the idea of blasting soil for tillage first was freely offered to the public through advertising and the editorial matter of farm papers, many unjustified and foolish claims were made for it, and a great many mistakes were made in the actual blasting. These claims and mistakes are to be regretted, because they led to barren or damaging results and to uncalled-for criticism of proper blasting.

As a general statement of the proposition, it may be said that soil blasting is to be regarded largely as intensive tillage. Its benefits are derived from its physical breaking and mixing, opening and loosening of the soil, and show themselves in the form of better drainage, an increased supply of moisture in dry weather and better root penetration, and because of these, in the greater fertility of the soil.

The movement to blast soil was at first popularly called "deep plowing" or "plowing with dynamite," but most farmers have come to know that blasting soil is in no sense plowing it. Blasting will not replace ordinary plowing, nor can plowing be made to do the work of blasting.

The whole matter of orchard tillage and feeding must be taken up when soil blasting for the benefit of trees is to be considered intelligently. Blasting is but one spoke in the wheel. Much of the misconception which exists to-day regarding the value and benefit of blasting orchard soil is due to failure in grasping this fact.

The subject necessarily is a technical one, and this bulletin must deal with chemical and mechanical processes of the soil, using technical language to some extent. But as far as possible the matter is kept to broad general principles known and accepted by the great majority of agriculturists. The problem is to find out whether or not the kind of tillage which blasting gives will produce beneficial results, and produce them at a cost within the reach of commercial orcharding.
This hole was blasted out when the ground was much drier than at the time the crater in the other picture was blown open. Instead of the sides of the crater packing, they loosened and crumbled. But even this ground is not as dry as it ought to be. Also a subsoil blast never should blow out a "hole." See page 131.

What An Orchard Soil Must Do

When attempting to form judgment of soil tillage by blasting or to explain it, we should have clearly before us what we want to do with the soil and what we expect the soil to do for trees.

The purpose or idea of cultivation of orchards is to get profitable growth and yield from the trees. That is obvious. We want the greatest net profits possible under the conditions of each orchard. No one pursues a system of cultivation for the sake of the system itself, although the farmer or fruit grower does a great deal of tillage work rather blindly and without knowing just why he does it or understanding the soil processes he is dealing with.

But it is clear that to make trees grow and yield to their maximum capacity, requires so far as the soil is concerned, enough water, sufficient of the right plant foods, and root anchorage and feeding space. These 3 essentials for growth are delivered to trees only by the soil, and the work of the soil consists in supplying them to the trees. It must be in condition to deliver them.

The Soil Problems in Orchards

Correct fundamental education in the principles of soil nature and management is so universal nowadays that the primary facts regarding the growth of plants, and their feeding habits, need not be discussed in detail in this bulletin. It is enough for the purpose to say that every

The Plant Foods reader is presumed to accept the facts that the plant foods which have to be supplied are nitrogen, potash, phosphorus and lime. These are the only ones out of the 20 or more elements used by plants as food which run short in the soil, largely because they constitute the great bulk of the materials, aside from water, that are taken up by trees. The source of supply of these important elements are, on the one hand,
artificial fertilizers and manure, and on the other hand, the soil itself (though nitrogen is derived from the air by means of soil processes).

The water problem is not less well defined and understood. To some extent it consists in draining away surplus water from wet places and swamps, and in making certain of the effective drainage of all land during winter, spring and rainy periods of summer. To a greater extent it is a matter of storing enough water for the use of the trees during the growing season. No orchardist questions the fact that the lack of moisture very often is the limiting factor in growth and crop production. The moisture problem perhaps is the most serious one which fruit growers have to face.

Root anchorage and feeding space (considered as one factor) give relatively less trouble than either a correct water supply or a proper supply of plant food. The latter factors must receive attention in all soils; the former only in certain soils of a hard or uninviting nature, or which are in bad condition owing to improper treatment. A light, porous, fertile soil offers no difficulties to roots in their penetration and food gathering, but a hardpan soil, a heavy clay or a cemented gravel soil does offer serious difficulties.

All orchardists agree that an extension of the root anchorage and feeding scope of trees is beneficial and desirable. Authorities continually remind us that we should drive the roots down away from the surface. One of the tests of the root anchorage and spread of a tree is to examine its roots for the size and nature of their growth. If they are long, ropelike and few, the tree is starving. If they show as a mass of fibers growing from well proportioned main branches, which extend to a fair distance in every direction, the soil is full of the needed foods and moisture. Only trees which are firmly and deeply rooted will stand up against windstorms and under loads of fruit. It is largely to bring about the conditions outlined that orchard ground is cultivated.

What Soil Is

The material we call soil may be described as the outer layer of the earth. The soil includes loam, clay, sand, gravel, boulders and even ledges of rock. To limit the soil to the earth penetrated by roots would leave out other material underneath of exactly the same stuff. To limit it to what we call loose earth,
leaving out rock, shale and the like, would not be correct, since the rock and the soil are composed of the same elements. Often the point where "soil" begins and "rock" ceases is indistinct, as in the case of hardpan, for instance.

The loose earth, or ground, is only particles of rock that have been more or less changed by and mixed with the remains of plants. There was a time when there was no loose soil. The surface was rock. As the seasons passed, water dissolved and wore away particles of the rock. After a time mosses and rock plants appeared and sent their roots into crevices. The roots grew and helped to split off other fragments, and when the plants died their material gave off acids which helped the water to dissolve more rock and to dissolve it faster.

Frost and heat from the sun hastened the processes till the softer minerals separated from the harder ones, and what was not washed away by running water caved in and became mixed with dead moss and the decaying roots and stalks of grass and other plants.

This is soil at the present time, whether it is hard or soft.

The top-soil of cultivated land ordinarily shows a much more advanced stage of this breaking down process than the subsoil. The top-soil, which usually is the layer reaching to the furrow depth, generally is darker colored, from the greater amount of remains of plants it contains. It differs from subsoil in porosity, moisture content, bacterial activity and in other ways which will be explained fully farther along in this bulletin.

Whatever the difference, it is largely a difference in the stages of decomposition or disintegration of the mineral particles, and of the amounts of organic matter present. Both surface and lower soils are essentially of the same chemical make-up and they both may have come from identically the same kind of rock. The ground near the surface has been exposed to action of heat and cold and water and air and plants, and has been changed more than the ground under the surface. The more the soil is broken down from the original rock the finer the particles are, and in general, the more fertile it is.

It is well at this point to call attention to the latent strength in the soil, to counteract any tendency toward the belief that you must put back in as much as you take out. The soil is not a sort of empty mill into which you pour plant food and take out crops. It is to a large degree an inexhaustible mine of many plant foods.

As evidence, look at the immense growth that has arisen from it in moss, weeds and forests during the thousands of years past. If all this growth were piled up it likely would weigh as much as the soil itself to a great depth. In the soil and air now, waiting to be released and used, is substance enough to create food for all the people of the earth for years without end. In the soil of your own orchard and farm you likely have nearly all the plant food elements your crops ever will need. Make them available for roots, add to the supply the few that are short, and in crops you can profit from nature's riches as surely as though you were digging gold or coal.
The Relation of Tillage Blasting to Soil

That "tillage is manure" is no new thought. The phrase itself originated a great many years ago. The proof of its truth lies in the very nature of soil itself, which has been explained in the preceding chapter. Tillage, which is the stirring and mixing of soil, promotes and helps these

Tillage Produces natural processes which first changed the rock into soil, and which now tend to make the soil fertile.

A good, deep plowing, followed by thorough harrowing, opens up the soil so that roots can penetrate it easily. It introduces air. It helps to maintain moisture in dry weather. It exposes a new part of the soil to frost and to sun. A new supply of the plant food elements which the soil contains is liberated, or it is better to say their liberation is hastened, and trees are given a better chance to grow.

The so-called "run-down" or "worn-out" soils contain almost as much of most plant food elements as ever. But instead of the soil being soft and mellow, it has reverted and become harsh. A run-down soil shows under chemical analysis a composition not greatly different from what it does before becoming exhausted or after it is made fertile again. The only vital difference is the state or condition of the plant food elements.

Tillage alone of course will not keep land from running down. Plants also are needed for supplying vegetable matter in the soil. Their dead roots and stalks hold the particles of the soil in crumbs, increase its moisture holding capacity and help to maintain conditions under which further decomposition occurs continually. Without tillage the plants will not grow or at least will not become mixed with soil farther down than a few inches.

Cherry trees three years old, with corn intercrop, which certainly takes some plant food. The soil naturally is no better than in the other part of the same orchard, shown on opposite page, but it was well broken up with explosives.
Under wild or forest conditions with no tillage, the fertility of the soil is maintained and even increased, but the processes are very slow and the result is long in coming. In orchard soil the processes must be hastened so that the natural forest changes of 25 years take place in one.

When an explosion takes place in soil, the gases escape in all directions from the place where the dynamite charge was located. Those gases which start downward and sideways soon curve upwards. They travel sideways several feet through the soil. They lift the soil in mass and make it break and crumble, and can be detected rising from the ground over a circle 10 to 15 feet in diameter about the position of the charge.

The gases of an explosive will rebound from a substance that is extremely hard or resistant, but they try hard to travel in a straight line in the original direction. When confined in hard soil, they strike against the resistance, and because the mass of soil is not firm enough to turn them aside, it is broken and crumbled. They smash right through compacted sections. This fining and crumbling action can be compared to the effect of pounding up a brick with a hammer. The tens of thousands of particles that had been clinging together in one hard mass are separated.

It is this fining and loosening which makes so valuable the particular kind of tillage which blasting gives. (It is intensive tillage—the kind which is "manure.") In modern agricultural practice intensive tillage is recognized as one of the best means of securing large crops—in fact, it is recognized as a necessity in orchards and in fields and gardens where intensive crops are grown. Blasting is tillage of the most intensive kind it is possible to secure by any practicable means.

The limit of plowing, even with deep tillage implements and subsoilers, is 16 to 18 inches. The shallowest blasting should reach to a depth of 36 inches,

In this orchard the trees are seven years old, but much smaller than the other, three-year trees. The fine growth of clover proves that top soil is fertile and in good condition, yet it does not grow trees as well as the blasted soil.
and the average work is done so as to reach to 48 inches or deeper. The real significance of such deep, intensive tillage is so far beyond the mere superficial appearance that it must be explained in separate chapters.

**How Root Growth is Helped by Deep Tillage**

A mature apple tree should have a root system spreading twice as wide as its spread of limbs, with some roots at least 10 feet deep, and a large part of the root system deeper than 2 feet. With roots less well developed and distributed, the tree is bound to suffer from lack of water, and plant food, and possibly from wind.

Fully developed peach trees have root systems smaller in proportion than apple trees. Pear, plum, quince, cherry, nut trees, citrus fruits, and the semi-tap root shade trees in mellow soil develop root systems not greatly different from apple trees in extent. Some ornamental trees, such as Norway pine and shagbark hickory, often grow half as deep into the ground as the trunk is tall. Grape vines have roots extending in every direction to a length out of all proportion to the size of the vines above ground.

These developments occur only when the ground is as loose, fertile and well watered as it should be. In orchards or hardpan soils and neglected soils, the roots grow out to a length less than the length of the limbs. They go down until they strike a compact layer of clay, a layer of hardpan, or the water table. Unless forced and coaxed down by cultivation, they grow up until you can see them where they bend above the surface.

The apple trees in these pictures were planted 19 years ago, in soil with hardpan about a foot under the surface. The tree at the right, in the picture, was planted without breaking up the bed with explosive; that at the left set in blasted ground.

Today some of the trees not growing in blasted ground are dead, while all those in blasted ground are living. Those in blasted ground average 25 feet high, and in unblasted ground 18 feet. The former trees have an average spread of limbs of 25 feet; the latter, 16 feet; while the trunks of the two sets of trees measures 3 feet 7 inches and 2 feet 3 inches, respectively. In the blasted ground the trees stand "shoulder deep," and over the unbroken hardpan the roots are raised above the surface, as the pictures show.

This is one of the most striking instances of the damaging effects of a hard and impervious soil that has ever been examined carefully and photographed. (Geo. W. Brown, Mount Cory, Ohio.)
The big root systems can be picked out by the appearance of the trunks and tops of the trees. No small, scrawny trees have well-developed and widely extending roots, nor will any large, thrifty trees have short and meagre roots. A tree that regularly grows and ripens a heavy crop of good sized fruit must have a big, deep root system. Any tree that does not cannot do the work. It follows, in view of these facts, that every orchard and ornamental tree should have roots extending as wide and as deep as possible. One or 2 feet deep is not enough. With roots only at such depths the trees exhaust the little bit of moisture within their reach during 3 or 4 weeks of rainless weather; or worse, they may be blown over by the first stiff wind.

Young trees have even greater need of proportionately big root systems than mature trees. Their roots need to go down 3 feet at least by the end of the second year after their planting and should extend laterally 6 to 8 feet then, even if the trunk is only 4 feet high. All that is said about root growth applies equally in the case of the newly planted tree and the tree that has been in place many years.

**The Causes of Restricted Root Growth**

The limiting factor as to depth of root growth may be some form of hardpan or cemented gravel, compact clay or other soil, poor drainage, or simply that the soil contains neither enough water nor enough available plant food. An idea of the difficulty encountered by roots in penetrating soil can be had by noting the method of their growth. A hair-like or pin point of a rootlet presents its tip in the direction it is growing. This new tip then expands like a bud in the spring, pushing back and lifting the soil or earth out of its way.

When the soil is soft and porous, the roots find little difficulty in penetrating it, because its minute air spaces serve as ready-made tunnels; but when the soil is compacted or cemented, as it is in hardpan, in hard gravel deposits, and in all harsh soils having little organic matter, the delicate, minute roots are compelled to do work which almost would defy a steel rod.

True hardpan is semi-rock. You cannot crumble off the edges of a chunk with your fingers. The softer type can be cut with a sharp knife, as clay can be cut, but the point of the knife cannot be forced into it without pressure or pounding. It is not surprising that such soil resists root penetration.

A hardpan layer, or one of clay, plowsole or other structure, can be compared to a plank floor underground. The roots will run along it in the softer soil, but they will not penetrate it. When a young tree is planted in a small hole dug in compact soil, it is, practically, in a wooden tub. The roots have to force their way through the hard sides in order to develop as the roots of a tree should.

The compact layer of soil may occur within 6 or 8 inches of the surface of the soil, or may be down a foot or 2 feet or more. Where within 2 feet of the surface, it often forces the roots to lift the crown of the tree entirely above the surface. If the entire root anchorage and feeding space of a tree is confined to the first foot or two of soil, it cannot grow or yield to anything like its maximum capacity.

To help to make clear the great difference in the case of root penetration
through hardpan, stiff clay or other tight soil, as against field soils in mellow condition, a statement of the amount of air space in soils may be of value. When a hardpan, clay or gravel soil has been thoroughly compacted by water or other agency so that the particles are packed as close as possible, the air space (or pore space or porosity) is only 5% to 10%.

The soil is 90% to 95% solid. This is the hardpan, cemented gravel and plowsole condition. But the average air space in soils in good condition is 6 to 13 times as much, as the following table shows:

**Approximate Amount of Air Space or Pore Space in Soils in Good Tilth**

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Approximate Air Space</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean sand</td>
<td>33 Per Cent.</td>
</tr>
<tr>
<td>Coarse sand</td>
<td>40 &quot;</td>
</tr>
<tr>
<td>Medium sand</td>
<td>41 &quot;</td>
</tr>
<tr>
<td>Fine sand</td>
<td>44 &quot;</td>
</tr>
<tr>
<td>Sandy loam</td>
<td>51 &quot;</td>
</tr>
<tr>
<td>Fine sandy loam</td>
<td>50 &quot;</td>
</tr>
<tr>
<td>Silt loam</td>
<td>53 &quot;</td>
</tr>
<tr>
<td>Clay loam</td>
<td>54 &quot;</td>
</tr>
<tr>
<td>Clay</td>
<td>56 &quot;</td>
</tr>
</tbody>
</table>

The nature or character of the root growth is modified by the comparative mellowness of the soil. The ideal feeding roots, it is everywhere agreed, are fine, fibrous and not long. The main or anchorage roots should extend well

The nature of root growth of fruit trees depends on the condition of the soil in which they grow. The ground was dug away from the roots of two trees, leaving the main roots in their original positions—(See next page)
out from the tree and down deep, gradually tapering from a thick base to a
slim point. All along them the tendril-like feeders should grow out like the
legs of the so-called "thousand-legged" insects.

In a tight soil the main roots usually grow short and stubby, with few of
the fine feeding roots. In a very poor soil the main roots lengthen into veri-
table ropes, traveling on and on in search of food. They are usually almost
bare of feeders. Under any conditions of soil except that of the best tilth an
excessive part of the strength of the tree has to go into root building and root
penetration, rather than into food gathering. Too much time is consumed in
growing the root. Five years may fail to develop a root system equal in food
gathering capacity to a system developed in one year in soil of proper texture.

The limited digging usually done in making holes for planting trees serves to
give the roots a brief start. The hole should be dug at least 3 feet deep and
4 feet square, but few indeed are the instances of the digging of such large
holes in commercial orchard planting. The usual prac-
tice is to scoop out just enough ground to let in the severely trimmed roots to the required depth.

Quite often young orchard and shade trees are set in
holes not more than a foot deep and 18 inches wide. The sides of the holes
frequently curl the ends of the roots back like clinched nails. An examination
of trees that have been dug up or washed out a couple of years after they had
been planted in dug holes, shows that masses of matted and twisted roots have
been confined in the hole that was dug, almost like the roots of a large plant in
a small flower pot.

How to Secure Big Root Development

The way to do this is to break up the soil with tillage, and to make it fine
and porous. Tillage with plows and cultivators can be extended to a depth

—Note how the hard ground under the one tree kept practically all its roots in the top two feet of
soil. The soil under the other tree was lighter and more porous, but not fertile, consequently
the roots grew like long ropes, traveling many feet in all directions. Both are poor root systems.
of 8 inches without trouble. By using subsoil attachments and deep tillage
disk implements 18-inch tillage is practicable.

Deep Tillage Insures Where it is desired to go deeper, hand digging and
Big Root Systems blasting are the only means available. Hand dig-
ging of all the soil is impracticable in commercial
orchards, but if the cost does not matter, the ground of home fruit gardens and
lawns can be worked over by hand to a depth of 4 to 5 feet by digging wide
trenches and shoveling the ground back from each new trench into the old one.
This is a common practice in many European gardens.

Tillage by blasting is pre-eminently the most advantageous treatment for
the soil that is hard enough to restrict root growth or to hold free water. In a
previous chapter the action of a proper blast has been described. It is clear
that the explosion, in breaking up the hardpan or the plowsole or the layer of
stiff clay or cemented gravel; in opening cracks through the soil in every direc-
tion, and in crumbling and fining the earth to a depth of 4 or 5 feet or more, as you
place the charge, supplies just the treatment needed. By no other practicable
means can the soil be worked to an equal depth, and in no other way can
even the top 2 or 3 feet of soil be worked so thoroughly at a reasonable cost.

After considering the foregoing facts the thinking man will need no con-
crete examples of better root expansion in well tilled soil to convince him that
roots will develop when given the chance and the incentive.

Roots in Blasted The illustration on page 105 shows this so well that every
Ground reader should look at it now. Two young trees were
washed out of their beds. Both had grown one season.
The root system of the one in blasted ground is about 4 times the size of the
other, and it is of a better character.

In the orchard where these two trees are growing are many thousand set in blasted ground and a few hundred
in unblasted soil. Not as many died as a result of planting each 1000 in the deeply loosened ground as of each
100 in the unbroken soil. The growth made by each class of trees up to the end of the second year after planting
is shown in the pictures, which are of typical trees from each lot. (The Belmont Orchard Company, Charlottesville, Va.)
This example is not advanced as typical of all results. The growth that will be made by any tree cannot be predicted. Too many other factors aside from the condition of the soil enter into the matter. The fact that some trees in properly blasted ground have grown as much in Amount of Increased Growth 2 years as others in unblasted ground have grown in 4 years is no guarantee that all trees will do as well, or may not do better. If the blasting is not done right no benefit at all may be derived; indeed, there are cases on record where positive damage has been done to soil and to trees by improper blasting.

There are but few soils in which intensive tillage of any sort will not help the root growth of trees. Among them may be Soils That Should Not be Tilled Deeply mentioned loose, light sand, gravels and loams which are as porous and mellow as they should be without further loosening. The volcanic ash soils of some Rocky Mountain states need no deep tillage unless underlaid with more or less crusted lava.

Whether or not to blast loam soils to secure better root penetration depends on their character and condition. If they are deep, well drained and well supplied with humus, the chances are that little increase in root growth will be derived from any sort of deep tillage. But considerations in respect to moisture storage and the liberation of insoluble plant food nearly always call for tillage and yet more tillage. Roots of cover crops must penetrate the ground in order to keep soil fertile. Hence few soils aside from those named above will not be benefited by deep tillage.

Correct methods of doing the blasting to put soil into proper condition for root development and for other purposes are described on pages 131 to 138. On page 140 you will find a discussion of the length of time one thorough breaking up of the soil may be expected to last, and of how the needs of trees may be met both at the time of planting and years later, when the roots have extended themselves many feet in all directions.

How Soil Water is Governed by Deep Tillage

In every orchard soil the water problem is two-fold. Surplus water must be drained away and sufficient moisture for use of the trees during dry weather must be stored. Both purposes are served by tillage in ways that are made plain in the following explanations.

The drainage must be effective enough to take away the excess water quickly, but the flow of water must not be so fast as to leach or float away much plant food. Whenever the excess water is permitted to run over or through the soil in trickles, it leaches out available plant food. It Leaching should filter away—without delay or damming back, but still filter—through beds of fine, granular soil.

The water should escape at a lower level into a ditch or into a loose layer of gravel or sand that will carry it away. In orchards the level of standing water in the soil must be well below the depth of root penetration if the trees are to grow and yield well.

Conditions Necessary for Drainage

To a great extent the drainage problem is to put the soil in condition by tillage to act as a filter bed. The soil must be kept loose enough to let the water seep and percolate through. Layers of tight soil, such as compact clay
or hardpan, hold the water as though it were in a tank

**Proper Drainage** or a pan. It cannot escape except by evaporation. Such tight soil must be broken up to a depth that will permit the lowering of the water-table below proper depth for root growth.

If the layer is thin—say only a couple of feet through—all of it can be reduced to fine particles. When it is thicker than 4 or 5 feet it cannot be broken entirely through to softer ground below except at prohibitive cost, and the effort should be to create a zone of proper condition in the top 4 or 5 feet of the ground. From this the water should drain away into ditches.

Even in soil containing no clearly defined hardpan, the general texture and condition may be such as to make drainage poor. Tillage will remedy this condition, by opening up and fining the soil so that water can move about in it freely.

The statement of the porosity or air space of soils in the chapter on root penetration (page 112) will be interesting in this connection. In a hardpan or thoroughly compacted clay there is an average pore space of only 5% to 10%, but when the same soils have been reduced by thorough tillage to a proper condition of tilth they contain upwards of 40% on the average, or 6 to 13 times as much pore space. In other words, nearly half of the bulk of the soil is air space, open to the free movement of water. Naturally such well-tilled soils are well drained.

**Moisture Storage**

The amount of water that in a dry season must be stored somewhere in the soil, available for the trees, can be stated with a fair degree of accuracy

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A direct comparison in growth. The superior soil conditions brought about by intensive deep tillage are responsible for the gain of the one tree over the other. Such marked results are not always produced by blasting, however—only when the soil is of a nature and in a condition to respond quickly and heavily to the action of air, moisture and bacteria. (Auburn, Ala.)
in terms of inches in depth. It must be based, of course, on the needs of the crop of twig growth, leaves and fruit. For each ton of material grown (dry) it is safe to say that at least 3 inches of water will be used by the trees. If the orchard crop weighs 5 tons to the acre, which probably is less than the average, the amount of water required is 15 inches in depth over the acre. This amount meets only the actual needs of the trees, and does not allow for much waste through surface evaporation.

Fifteen inches of water is the net amount that will be required to make the growth and yield of the trees. Less water available for the roots will mean decreased growth and fruit production. If irrigation is not practiced, the one safe procedure is to store the required amount of water in the ground, for rainfall is uncertain, and cannot be depended on.

The capacity of a well-drained soil to hold water in a condition in which it is useful to trees depends on its structure and condition. Laboratory tests of average field soil in excellent tilth have shown in the first 4 feet down from the surface the amounts of water given in the table below.

**Amount of Water Contained and Useful in Different Soils When Tilth is Good—Top 4 Feet Fully Loaded**

<table>
<thead>
<tr>
<th>Amount of Water Stored by Soils</th>
<th>Amount water (inches deep)</th>
<th>Water weight</th>
<th>Unavailable</th>
<th>Inches available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse sand</td>
<td>7</td>
<td>11%</td>
<td>3%</td>
<td>5</td>
</tr>
<tr>
<td>Light silt loam</td>
<td>14</td>
<td>21</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>Fine sandy loam</td>
<td>11</td>
<td>18</td>
<td>5</td>
<td>8 1/2</td>
</tr>
<tr>
<td>Clay</td>
<td>16</td>
<td>30</td>
<td>17</td>
<td>7 1/2</td>
</tr>
</tbody>
</table>

The superb soil conditions produced by intensive deep tillage are nowhere of more value than in orchards of citrus trees. These two trees, both Valencia orange, both 15 years old, were planted side by side. The one in unbroken soil is only 8 feet high. The other is nearly three times as high and more than twice as broad. (E. C. Franzen, Santa Ana, Cal.)
These soil types are named for purposes of illustration. The moisture content of other soils can be judged from these figures.

The figures in the first column indicate that clay and light silt loam to a depth of 4 feet might contain enough water for average crops of fruit, while in coarse sand and fine sandy loam trees would run short. But only part of the water can be used. In clay soil, for instance, trees will wilt when the ground still contains about 17 per cent. of water. This leaves only 7 1/2 inches in depth of water out of the total supply of 16 inches when the soil is filled to capacity, that the trees actually can use. The proportion of water that can be used in the other soils is shown likewise in the table.

It follows that all the water that can be stored in the top 4 feet of any soil is not enough for a fair crop of fruit. The supply must be increased. The trees must get a part of their supply from the subsoil beneath the 4 foot level. This brings us to a consideration of the manner in which water is stored in the soil and the ways in which it moves about. In previous reference to the pore space or air space in soil (page 114), the free drainage of excess water was mentioned. Water which will percolate and seep down through the pores of the soil owing to the action of gravity is harmful to all fruit and ordinary shade trees. The roots cannot or will not take it up in this form, and are damaged by it.

The only form in which roots take up water is when it clings to particles of soil as films. This is called capillary water, because it is held to the particles by capillary force. What this force is and the form in which the water is held can be illustrated better than described. Put your finger in water and...
it comes out wet. Put it in quicksilver, and it will come out dry. Some of
the water is held to the skin by capillarity, but none of the quicksilver is so held.

After excess water has drained away from the soil particles, they are wrapped
in films of water which can be more correctly called moisture. This moisture
is held to them by capillarity until it is taken away by evaporation or by roots.

If one particle should happen to have less moisture than its neighbors,
capillary force causes some of the bigger supply to creep from surface to sur-
face till the amount is equalized throughout the soil. The movement of capil-
larv moisture is not limited to the one direction—downward—as free water is
limited. In this form moisture moves upward and sideways as well. The
movement can be illustrated by the movement of oil in a lampwick, or of ink
in a blotter.

Now the movement of capillary water toward the surface from a depth
greater than 4 feet is free and abundant when soil conditions are right and
there is an abundant supply below. It, however, depends on the fineness and
arrangement of particles and the pore space of the soil. The soil must be fine;
the particles must touch one another; but they must not be so packed or jammed
together that the pore spaces are squeezed shut. If the particles are round,
they should touch one another only at minute points on their surface, as
apples touch when properly packed in a box. The logical way of feeding
moisture to trees or plants is to send the roots down after it. Capillary move-
ment, however, brings the moisture to the roots as they use up the supply
they are in contact with.

The reason behind the necessity for a comparatively loose condition of
soil is easy to see when we remember the films in which moisture is held. Reduce
the surface space of the particles and we reduce the surface area which can
carry moisture films.

The size of the particles governs directly the extent of the surface area
in a given bulk of soil, and consequently the amount of film moisture it holds.
As it is illustrated often, a solid rock in the form of a
Film or Capillary cube, measuring 3 feet high, 3 feet wide and 3 feet thick, has 54 square feet of surface area. Reducing such a
Moisture Supply rock to pieces measuring an inch on a side increases the
surface exposed to nearly 2000 square feet. Reducing the pieces to the size
of soil particles increases the area in proportion.

As applied directly to the soil, the facts regarding the number of particles
and their surface area are striking and wonderful. The table below gives the
figures.

<table>
<thead>
<tr>
<th>Soil</th>
<th>Number particles per pound of soil</th>
<th>Sq. ft. surface area per pound of soil</th>
<th>Sq. ft. surface area per cu. ft. of soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse sand</td>
<td>1,326,600,000,000</td>
<td>405</td>
<td>40,500</td>
</tr>
<tr>
<td>Medium sand</td>
<td>1,724,700,000,000</td>
<td>473</td>
<td>44,500</td>
</tr>
<tr>
<td>Sandy loam</td>
<td>2,914,000,000,000</td>
<td>816</td>
<td>66,600</td>
</tr>
<tr>
<td>Silt loam</td>
<td>4,287,000,000,000</td>
<td>1340</td>
<td>104,000</td>
</tr>
<tr>
<td>Clay loam</td>
<td>6,811,400,000,000</td>
<td>1825</td>
<td>136,500</td>
</tr>
<tr>
<td>Clay</td>
<td>8,231,100,000,000</td>
<td>2000</td>
<td>142,000</td>
</tr>
</tbody>
</table>

The significance of the figures in the last column will be plainer when it
is recollected that an acre contains about 43,000 square feet. Each cubic foot
of medium sand contains about an acre of surface of particles on which moisture
film can be held, and each cubic foot of clay contains upwards of $3\frac{1}{2}$ acres of such surface. Therefore an acre of soil to a depth of a foot may contain upward of 43,000 to 140,000 acres of moisture film when in proper condition.

The figures are illuminating in respect to the varying moisture-holding capacities of different soils. Sand has less than one-third of the capacity of clay. These differences should be kept in mind.

The Moisture Supply Depends on Depth and Thoroughness of Tilth

The figures for the amount of water soil can hold are based on soil in first-class condition of tilth, with normal porosity of 30% to 50% and with the usual amount of organic matter. Soil that is compacted, cemented, run together or lacking in humus will not have anything like the stated amounts. Also the movement of water—the drainage of free water and the movement of capillary water in dry weather—will be restricted very greatly.

Emphasis must be placed on this matter of organic material in the soil. It constitutes one of the most important elements that go to make good tilth. If organic matter is lacking the soil will run together and within 2 or 3 years will become harsh and unpleasant in spite of the most intensive tillage.

The way to insure the necessary 15 inches or more of net depth of water needed to grow full-sized crops is to fine and loosen the soil thoroughly to a depth of 4 feet or more in order to store the maximum of moisture, and then have the ground below this depth in such condition that capillary moisture will rise without restrictions.

Tillage must be thorough and deep to promote drainage and to put the

One tree grew from spring to fall in blasted ground; the other alongside it in unblasted ground. The trees both are Yellow Transparent, 2-year when set out, and of equal size then. (E. G. Sexton, Canton, Ga.)
soil into condition to store sufficient moisture. If it is not the soil below the
furrow depth becomes compacted and hard.

Deep Tillage Demanded The particles of soil run together till their water-
holding capacity is only a fraction of what it
ought to be and can be under normal conditions of tilth.

Something can be done toward increasing the moisture storage capacity of
soil by breaking to a depth of 16 or 18 inches with subsoil plows and deep til-
lage implements. But the execution done by proper
blasting is better in proportion to its increase in depth.

Subsoil Plowing Thoughtful orchardists will see that there is no practicable way of getting
the soil worked and loosened at sufficient depths other than by blasting it. Blast will do it—and in connection with regular and cover
Blasting Soil crops to keep up the organic matter will insure each season a
supply of moisture sufficient for heavy crops in dry weather.

In case layers of hardpan or clay interfere with the movement of water, they should be broken up. Soil should be examined thoroughly for any such
conditions.

The conservation of a moisture supply by shallow surface tillage is a gen-
eral practice. It need not be described here other than to say that a 2 or 3
inch layer of loose, dry soil or dust will isolate
Surface Mulch Required the moist soil beneath and prevent the escape
into the air of the water it carries. Deep tillage
will help to provide the storage of a supply of water, but it will not conserve it. This moisture conserving (mulching) tillage on the surface is absolutely necessary.

But no amount of surface tillage will conserve moisture that is not stored in the soil. Enough rain falls during the growing weeks of some seasons to supply the needs of heavy crops, but every orchard in which the soil is not deeply tilled is bound to suffer from drouth frequently. The outstanding
fact is that deep tillage is required before an adequate supply of moisture can be assured every summer.

How Deep Tillage Increases Fertility

The proper proportion for the different plant foods previously mentioned
in the soil cannot be stated exactly, because different plants and trees require
different amounts. A slight excess of any element will do no harm.

The so-called chain theory of plant food needs has been proved true so
often and so extensively that it is to be considered
Balancing Plant Foods no longer as a theory, but a fact. Briefly, this
rule is to the effect that the thrift or growth of a
tree or plant is governed by the amount of that plant food in which the soil is
weakest, proper balancing considered.

If a certain soil contains—we will select arbitrary figures for the sake of
illustration—in each cubic foot 6 units of nitrogen, 10 units of phosphorus and
20 of potash, while the need of the crop grown in this soil is 10 units of nitrogen,
20 of phosphorus and 12 of potash, the crop will not be a full one. It likely
will be three-fifths of normal size, because growth will be held down by the
lack of enough phosphorus and nitrogen. The oversupply of potash in the
soil is of no use because one plant food cannot be used to any practicable
extent in place of another.

This one illustration is enough to make clear the idea of the necessity for
having all plant foods present and available in abundance. There is nothing
mysterious in the fact of a crop failure, nor need there be much doubt about what constitutes proper fertilizing of land.

But knowing what elements of food are needed is only half the battle. It is equally important to know where to get the necessary material and how to make it available for roots, certainly, cheaply and quickly.

Plant Foods of the Soil  As stated on page 106, the usual orchard soil contains an abundant supply of available plant foods, excepting only of nitrogen, phosphorus, potash or lime, which may or may not be present in sufficient amounts.

The nitrogen can be secured in unlimited quantities from the air and put in the soil by proper use of legumes.

The lime must be added in the usual way.

The Phosphorus and Potash Problem

A chemical examination of your soil, to a depth of 1 to 6 feet or more, if it is clay, loam or sand, likely will show figures for the amount of potash and phosphorus present that may surprise you. To make them apply more easily to the usual field condition, the following data are based on an acre, but of course do not apply accurately to all soils.

The amount of potash in the soil of “new ground” to a depth of 7 inches, the usual furrow depth, will run as high as 60,000 pounds. It may be as low as 20,000, but it will average up to 40,000 to the acre. The soil to a depth of a foot, therefore, contains more than 100,000 pounds, or 50 tons of actual potash. To a depth of 4 feet the amount is 200 tons to each acre.

The growth of shade and ornamental trees is governed by exactly the same principles as that of orchard trees. They must have enough moisture, nitrogen, potash and phosphorus, and must have root anchorage and feeding space. In a yard or lawn the soil conditions are such usually as to be benefited particularly by the intensive deep tillage given by blasting, as these two pictures demonstrate. (St. James, Mo.)
The amount of phosphorus is smaller, but still is formidable. It runs as high as 25,000 pounds to the acre in 7 inches deep of soil in some of the better new lands, falling to only a few hundred pounds in poor lands. In all new lands in good tilth it will average around 8,000 pounds to the acre in the clay, and about 2,500 pounds in loam. In soils that are run down the phosphorus usually is used up till less than 1,000 pounds and sometimes only 200 pounds to the acre remains in the top 7 inches.

Taking the above average figures, each foot deep of fertile loam contains upward of 2 tons of actual phosphorus and each foot of clay, 8 tons. Four feet of soil over an acre contains 8 tons and 32 tons respectively.

The different fruits and other crops require varying amounts of plant foods, as mentioned at the beginning of this chapter, but a sufficiently clear idea of their average requirements can be secured by examining the demands of a wheat crop.

**Amount of Plant Food Used by Trees**

Wheat requirements are not essentially different from those of apple, peach and pear trees.

Trees use the most of their potash and phosphorus in growing leaves, twigs and bark, and little in growing the fruit. The food elements in the leaves of trees, of course, are returned to the soil each autumn, but those used in making wood are permanently removed from the soil.

Erosion and leaching take away some plant food. This loss, of course, must be added to the amount carried away in crops. Tests have shown the loss to be about one-eighth of the amount consumed by average crops. Nearly all of this comes from the few top inches of soil. The top inch or two of some soils is leached "dead."

The store of phosphorus in the soil, we have seen, is much less than that of potash—averaging one-half to one-fifteenth as much—but the amount consumed and carried away by crops is nearly equal. Therefore, the phosphorus supply is subjected to a much greater drain in proportion, and will be exhausted in much less time. In many soils it is already seriously depleted, if not practically exhausted.

In the chapter which described the formation and nature of soil, it was pointed out that heat, cold, water, air, bacteria and other natural agencies had manufactured Insoluble

**Natural Plant Foods**

loose earth commonly called "soil" by disintegrating and

It is extremely important that an evergreen tree should have its roots below frost-line, on account of the evaporation of water from its needles during the dormant period. Cut off evergreen roots from moisture and they quickly dry out. The resin in their sap hardens. When this happens the tree is doomed, because the sap never again will soften and flow.
decomposing rock. That is, they broke it down from solid rock to the softer stage, of more or less fine particles.

Now, plants require their food to be dissolved in water before the roots can take it up. They take their potash and phosphorus and nitrogen and other foods as soup instead of solids. But these food elements will not dissolve in water as they exist in the soil. They first must go through certain chemical changes.

The agencies which produce the changes are the same ones which brought along the processes of decomposition of the original rock so far—water, air, bacteria and the others that have been named. To these may be added organic matter and lime. In the ordinary course of events in an unworked soil, such as in a forest or a field only plowed, the subsoil is but little disturbed and none of these agencies is permitted to do much work. An occasional root penetrates deeply, a mole or a squirrel or other animal may dig a tunnel, producing the conditions necessary for the liberation of the insoluble food. But in the main the freeing of the locked-up elements takes place at a very, very slow rate.

The problem of the orchardist is to hasten the processes of liberation so that the natural chemical changes of dozens of years will take place in one season. To accomplish this he has only to expose the particles of the soil to the action of his helpers, the water, air, lime, organic matter and bacteria. Moisture liberates plant food directly by dissolving such of it as will yield, but whenever there is excessive free water some of the food that is liberated is carried away with the surplus water that drains out of the soil and some more of it is changed back to unavailable forms.

Liberations of Natural Plant Foods

The most rapid liberation of insoluble foods takes place when the water in the soil is limited to the moisture held by capillarity. This water wastes none of the material it frees. Each soil particle contains some of the plant food and its film moisture extracts this and holds it until the roots get it by taking up the moisture.

Air produces oxidation of the insoluble elements (as rust) in connection with a proper supply of moisture. Organic matter contains acids, which, released in the decomposing of the roots and leaves, act chemically on the locked-up food in the particles and free some of it. Lime acts to some extent in a similar way. But by far the greatest amount of liberation of the insoluble elements is due to the action of certain beneficial bacteria.

These beneficial forms of animal life cannot exist in soil that contains little air, or which has either too much or too little water, or little vegetable matter. Nor can they exist when the soil lacks lime. As soon as the soil is made normally porous, as described on page 114, the excess water drained away and a proper supply of moisture held as films about the particles, and when vegetable matter in the form of roots and stalks of plants is introduced, the bacteria begin to multiply and become very active. Under favorable conditions they are able to liberate more insoluble potash.
and phosphorus in 1 or 2 years than has taken place in 100 years without them.

On the majority of farms some potash and phosphorus has been added to the top-soil in commercial fertilizers and manures, but the quantity is small compared to the original natural supply.

Recapitulating, the liberating of the insoluble potash and phosphorus that is in the deeper soil calls for the introduction of air and the presence of capillary moisture and plenty of organic matter. The only way in which the moisture can be stored and maintained in dry weather, is by fining and loosening the soil, which automatically brings the necessary porosity and air supply and conditions for root penetration.

The presence of a large weed and grass growth proves that the soil is fertile. It is not detrimental, but helpful, in the orchard after July. Under a system of shallow surface tillage during the spring months and intensive deep tillage every few years the food supply will be kept up largely by nature.

The difficulty in an unworked soil is to keep plant foods, particularly potash and nitrogen, in an available condition. When bacteria are not active, the available fertility reverts to its original insoluble state very quickly.

Once the soil is loosened, cover crops should be planted immediately so that the ground will be filled with roots to a depth of 4 or 5 feet. This is the only way raw vegetable matter can be distributed below plow depth. Tillage itself will not make the soil granular and mellow. That is a Cover Crops result which comes about after proper conditions are established. The proper plants to select for this purpose are those which have abundant roots. If the regular crops meet these specifications they will do.

Weeds make good cover crops. Some of the more common weeds, such as wild carrot, ragweed, smartweed, mullen and others have the power to take from soil—even sandy soil—larger quantities of potash than cultivated grasses or crop plants do. They break down insoluble plant foods and store a heavy percentage in roots, stalks and leaves. On their return to the soil these stalks and roots serve the double purpose of organic matter and of carriers of avail-
able food. Throughout preceding pages no attention has been given to this power of plants to act as miners and refiners of insoluble native food elements in the soil. Their action in liberating locked-up elements is considerable.

To discuss the methods of loosening and fining the soil would be only to repeat what has been said in previous chapters. It can be done with a certain degree of effectiveness with deep tillage implements

Methods of Tillage and subsoil plows, but it can be done better by blasting. The explosives reach down where the tools cannot reach—with a thoroughness beyond comparison.

The vital point is to get the subsoil at depths below a foot worked thoroughly. To depend on the soil above this is to send a boy to do a man's work. The use of 3 or 4 feet of soil by the roots, rather than 7 inches, or one foot, obviously is bound to be of great advantage unless the top soil foot is exceptionally rich. The rate of liberation of the insoluble elements from one foot of soil seldom is great enough to provide food for the full crop. From 3 or 4 feet the amount liberated at the same rate will be 3 or 4 times as great, and is more likely to satisfy the trees.

Lime improperly applied will cause the soil particles it comes in contact with to give up all their plant food, and it will decompose organic matter very fast; hence its use should be planned carefully. Burned lime, either steam slaked or air slaked, is much more violent in its action on the soil particles than ground limestone. The latter is mild and slow when applied in any quantity; the former should be strictly limited in quantity and should be thoroughly and evenly distributed and mixed with the soil.

In soil that is properly porous and fine, lime applied to the surface is carried all through the ground to a depth of 3 or 4 feet within a comparatively short time. In compacted soil, as when the ground under the usual furrow depth has not been broken up for years, lime organic matter and rainfall—and roots—are kept near the surface while ground moisture and seven-eighths of the plant food that ought to be used are kept below, safely and uselessly—stored for the benefit of future generations of farmers.

The Nitrogen Problem

The relation of deep tillage to the supply of nitrogen in the soil is not so direct as to the supply of phosphorus and potash, but none the less definite. Tillage, together with proper accompanying orchard practices, will keep the soil supplied with all the nitrogen the trees need.

In Chile are deposits of nitrogen-bearing mineral, which, in the form of nitrate of soda, is used in
fertilizers to carry nitrogen into the soil. Other commercial fertilizers bearing nitrogen are cotton seed meal, bone, meat scrap, Nitrogen in Commercial Fertilizers and dried blood. In them the nitrogen costs 12 to 40 cents a pound at usual market prices. This nitrogen is an exceedingly expensive plant food compared with phosphorus, and compared with the value of the growth it makes, though its use in these high-priced forms may be profitable when well directed.

A cheap source of nitrogen, however, is the air. The air is 75% nitrogen. Over each acre of ground there is an unlimited supply of it. The cost of getting nitrogen from the air is small. In many cases enough Nitrogen in the Air other benefits are derived from the process to give a profit in addition to the nitrogen. Probably it is better to say that the processes which produce the nitrogen are required anyhow in nearly the same form to establish and maintain good soil structure and texture.

This atmospheric nitrogen gets into the soil as one of the components of organic matter—in leaves, stalks, roots and seeds. The plants which are richest in nitrogen are the legumes—clovers, peas, beans and vetch. But all plants contain some of the valuable substance.

The amount of nitrogen needed by orchards will likely be 50 to 150 pounds a season. Heavy crops of corn require 150 pounds. Light crops of wheat require as low as 48 pounds. The cost of these quantities of nitrogen if all is bought at current prices in commercial fertilizers is prohibitive.

Amount Used by Orchards

In the usual soil there is but little nitrogen. A chemical analysis likely will show a few hundred pounds to the foot in depth over each acre, though soils unusually rich in organic matter may contain several thousand pounds. But unlike insoluble potash Soil Supply Dissipated and phosphorus, on the ordinary farm nitrogen soon becomes soluble in the top foot of soil. When the leaves, stalks and roots carrying it decay, it is liberated, and in the free state any surplus not taken up by roots leaches away and is lost within a few months. On this account the supply in the soil can be kept up only by adding to it every year or so the quantity taken out by the trees and lost through incidental leaching.

The legumes gather more nitrogen from the air than other plants because of certain bacteria which accompany them on their roots, and without which they do not thrive. A ton of legume hay contains about 40 pounds of nitrogen. The different legumes vary a little in content of nitrogen, and in the amount carried above and below the ground. But in general it is near enough correct to count that every ton of dry plant growth of clover, Amount in Legumes beans, peas or vetch—roots, stalks, leaves and blossoms—will give you the 40 pounds of nitrogen. Since an average crop of these plants is a couple of tons or more, their annual use as cover crops will increase the supply of nitrogen against all losses without the addition of large amounts in commercial fertilizers.

Legumes get a large part of the nitrogen they use from the air and a smaller part from the soil. Before they will succeed, the soil must contain a little nitrogen and must be loose and porous. In a soil that is harsh and devoid of practically all nitrogen the start should be secured by first using lime and then turning under rye, or some other plant that will provide organic matter, thor-
It is the top-soil that under usual conditions of shallow tillage contains practically all the nitrogen. The subsoil contains little or none. The reason is that most of the organic matter carrying the nitrogen that is turned under is placed in the bottom of the furrow, or is distributed from this depth upward.

Under any tillage system, the bulk of the organic matter put into the soil must be merely plowed down. It cannot be mixed with the deeper soil immediately, except in the form of the roots that penetrate deeply and that carry down much nitrogen. It is not long before deeply broken soil becomes impregnated with a small amount of nitrogen as far down as it is loosened and powdered. This cannot help being of great advantage to trees, the roots of which occupy the lower soil rather than the top 7 inches. When the trees are compelled to get all their nitrogen out of the top few inches, or at most the top foot of soil, in orchards worked no deeper than the plow goes, they seldom get all the nitrogen they need because only part of their root system can get at it.

Too much stress cannot be placed on the value of a deep layer of loose, fine soil as a filter-bed that will catch escaping nitrogen and other plant foods. The excess water that percolates through 4 feet of fine soil particles loses much of any burden it carries, and this salvaged material is deposited deeply, where it is relatively safe from further leaching as well as convenient to roots under proper condition.

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At Lynchburg, Va., blasting the soil for shade and ornamental trees has become a recognized practice. Notice the excellent growth of new wood on the ends of the limbs of this elm.
peat, soils that are almost entirely composed of the remains of plants, rich in nitrogen in an insoluble form. Therefore, adequate supplies of free nitrogen are to be found only in soils that are well and deeply worked.

The methods of working the soil are unimportant, so long as they are thorough and effective enough. Deep tillage implements will do good work to a depth of 18 inches under favorable conditions. Blasting will do even better work to any required depth. The repetition of the full discussions of this matter on pages 114 and 120 is not necessary here.

Methods of Working Soil During years past some friends of soil blasting have claimed for it certain other advantages that never have been proved. It is unnecessary and undesirable to list them in this bulletin, for no exact data are available on which to base conclusions. Furthermore, whether or not such claims are true is of little importance, because of the overwhelming value of the direct physical tillage action of proper soil blasting, which cannot be questioned. Soil blasting is intensive deep tillage.
Treatment of Different Soils

Practically all clay and loam soils respond wonderfully to tillage blasting, requiring only the addition of lime, the required fertilizers and cover crops, of course, to make them produce record-breaking crops. But there are a few soils that differ in nature from clay and loam to such an extent that intensive deep tillage is of no benefit to them.

One way of making clear the proper treatment for each soil would be to describe every important soil in the country, giving its nature and suggestions for exactly the sort of tillage best suited to it. For instance, we might describe limestone soils, redshale soils, sassafras soils and so on down a long list, making clear the types of each soil. This, however, would be a cumbersome way of going about the matter.

Lynchburg, Va., where a great many ornamental trees are set in blasted ground. These trees show by the amount of new growth exhibited in the pictures that they have plenty of moisture and food.

Soils are classified by the Government and by agricultural authorities largely according to their origin, as is illustrated in the ones named above. Yet to the practical orchardist, with a practical problem in fertility and moisture supply to solve, the vital factor is first the size of the particle and second the condition of the soil with respect to amount of organic matter present in the particular land he has. Therefore, it seems that the things to talk about here are the structure, texture and condition of soils, rather than their origin.

About 10 types, or degrees of fineness of particle, usually are recognized, ranging from pure clay, through various degrees of silt and loam, to pure coarse sand. The clays have the finest particles; the sand the coarsest. As a general rule it can be said that the smaller the particle of the soil the greater the benefit it will derive from any sort of intensive tillage.

The fine particles seem to give up their natural fertility easier than the coarse ones—they respond more to proper cultivation. As the size of the particles increase, less and less plant food will be released from them under any conditions, and less and less improvement will be made by intensive tillage in the drainage, moisture storage capacity and nitrogen supply.
When the particles reach the size of SAND and especially COARSE SAND, with little or no clay or loam added, the soil has all the porosity it needs and the particles are located so as to give their greatest surface area per cubic foot of soil when the ground is packed about as hard as it ever gets. To loosen up such a soil decreases its moisture storage capacity, already low, without any other effects. Such coarse-grained soils should not be blasted.

Are composed of the remains of plants mixed with sediment Muck Soils deposited by standing water. The material remains muck instead of decomposing further and becoming loam, because of the absence of air and bacterial activity. They should first of all be drained of their excess water by proper ditching. This will leave them porous enough for best results without further loosening.

Vary greatly in structure and condition. Their moisture holding Clay Soils capacity is high, and they usually need draining. Some of them have clay and nothing but clay, compact and practically water-tight from top-soil to a depth beyond the reach of roots. Such a clay soil should be broken up and fined to a depth of about $4\frac{1}{2}$ feet under ordinary circumstances, as this is about all the depth that can be kept open and porous.

While in some clay soils the layer of clay may be thin—often only 6 inches—in others it is 3 or 4 feet, or even 5 or 6 feet thick. Under the clay there is often a layer of gravel or sand. Such soils should be broken up clear to the bottom of the clay layer, and if the clay is thin and near the surface, the breaking should extend into the layer of earth under it, at least through a total depth of 4 feet.

Also vary greatly in structure and condition, but almost universally they require the same sort of deep tillage for planting trees. Loam Soils They should be fined and loosened to a depth of at least 4 feet. Occasionally loam should be loosened deeper, on account of need for drainage. The subsoil of long-cultivated loam generally is very much compacted. These soils usually are fairly well drained naturally, but may require special attention in this respect. Coarse sandy loams and gravelly loams seldom require deep tillage.

And other layers of tight soil may be found in Hardpan, Cemented either clay or loam, and sometimes even in sandy Gravel, Bound Loams and Sands ground. The particles of the hardpan usually are very fine. This layer of compacted and hardened material may be as thin as 3 inches or as thick as 6 feet. It should be broken entirely through in every orchard where found. Stony Land Does not differ in tillage requirements from soil without stones. The stones seem to help in moisture storage a little, and in orchard soil are not regarded as a detriment if they are small.
How to Blast Orchard Soil

Proper preparation of ground for planting trees is little different from correct tillage of orchard soil between and under growing trees. The principles are the same and the mechanics of the actual blasting differ but little.

The first care in every case must be to see that the subsoil is dry. **THE SOIL MUST BE DRY** — the drier the better. Unless the subsoil is so dry that it has but little plasticity the action of an explosive will not give the maximum quality and quantity of tillage results.

The reason why soil cannot be blasted with proper results when it is damp or wet is easily shown. Strike a wet clod with a spade. Instead of loosening under the pressure the clod becomes compact and makes a solid lump. Now strike a dry clod in the same way and you will crumble it. If it is very dry you will pulverize much of it into dust. Damp and wet soil becomes compact under pressure. Dry soil crumbles.

If ground is wet or quite damp when it is blasted, the effect is only to make a ball-shaped hole 2 or 4 feet underground, more or less covered with loose earth. The soil for about a foot on all sides of the immediate spot where the charge of explosive was located will be compressed instead of shattered. The sides of the hole, so formed, and the bottom, will be tightly packed. A few cracks may extend into surrounding soil, but 95% of the effect of the blast will be confined to a sphere 2 or 3 feet in diameter, with positive packing instead of loosening. **THIS IS NOT GOOD SOIL BLASTING.** It will not give the benefits that have been described in previous chapters of this bulletin. Except in isolated instances it will disappoint anyone who tries it with the expectation of good results.

These two pictures are included to show two things. **One:** how not to blast tree beds; never permit the blast to blow dirt out, as these blasts are doing. Keep the amount of the explosive reduced to the point where the surface of the ground will be only heaved. **The other:** how a blast crumbles dry soil; the ground is drier in the left-hand picture, hence the soil crumbles to dust. You can see the stones among this soil, in the air. In the right-hand picture the soil is damper, and does not powder as well. See pages 103 and 104 for other pictures.
The conflicting results from "soil blasting" which have been noted in various orchard experiments and tests, and about which much discussion has been aroused, have been due largely to variation in the condition of the soil at the time of blasting. As might be expected with a new process, the methods of practice have not become standardized. There are as surely right ways and wrong ways of blasting as of plowing. Much of the blasting of the past few years has been done in ways that in the light of present knowledge could be expected to give but little if any benefit.

When the soil is dry at the time of blasting, the effects of the explosion reach out many times further than when it is damp, and the breaking and fining action of the gases is much more thorough and complete. If any cavities are formed underground they can be easily filled by running a shovel into the bed of the blast. In actual planting, the loosened dirt should be shoveled out.

In respect to the time or date of blasting, good results are derived when the work is done just before the trees are planted—provided the ground is dry. It is rather difficult, however, to bring the two operations together while doing both justice.

Trees usually should be planted when the ground is damp or wet. You can plant trees in dry ground successfully, however, though you cannot blast wet ground successfully under any circumstances. If you plant, in dry ground use two or three gallons of water about each tree.

Spring usually is the best season to plant in the North, but blasting ground in the spring before too late to plant trees is a matter of luck. Proper conditions occur at that season only once in several years. Sometimes you can do it; more often you cannot. Fall planting usually is not advisable in the North, though in the South it often is to be preferred. In fact, in the South, planting can be done successfully without interruption from the time the leaves drop in autumn till the buds open in the spring.

All things considered, blasting of orchard soil usually can be done to the best advantage in July, August or September, after a prolonged rainless period of weather. Sometimes the ground is dry enough in May or June; once in a while it is dry enough in October or later in the fall.

Blasting soil in the summer or fall for planting the following spring is entirely successful. The plan has many advantages. The action of sun, air, frost, water and other agencies during the winter on the loosened soil results in much increase in its fertility and cavities made by the blast become filled. A cover crop should be growing during the fall months in the blasted ground, whether the tree is planted or not.

When planting must be done in the spring and the soil blasting has not been done the previous fall, it is all right to blast if the subsoil is dry, and will conform with the tests given on page 131, but if it is wet, the better plan is to plant the trees without blasting, then to blast the soil about them during the following summer. This can be done with satisfaction. The details are explained on page 137.

The proper position of the charge in the soil depends on the nature of the soil. It should be deep enough to break the soil down 4 feet, and in many cases the effect of the blasting should extend deeper, even as deep as 6 or 8 feet, but such depths of blasting are advised only for a few kinds of trees. Individual comments on certain soil conditions are necessary to make clear the proper depth for charges.

It must be understood that intelligent placing of charges depends altogether
on examination of the soil with an auger or by digging. Without the tests it is guesswork.

The proper depth of the charge depends on the thickness of the hardpan layer. In any case the soil should be broken to a depth of 4 feet. **Hardpan** Usually, the layer of hardpan is so placed that the charge should be located about \( \frac{2}{3} \) of the way down through it.

In case the layer of hardpan is thicker than 4 or 5 feet, it is almost impossible to break it entirely through at a reasonable cost. The charges should be placed in such soil about 4 feet deep with the object of loosening and fining a section of the soil 4 feet deep, leaving the underlying hardpan intact. But it is best to break the hardpan entirely through to a softer, more open layer of earth underneath when practicable.

When there is loose or open ground below a relatively high and thin layer of hardpan, the charges of explosive should not be placed so near the bottom of the layer that the force of the explosion will escape into the loose ground below and only break the hardpan into large chunks instead of crumbling it. The remedy is to locate the charge higher in the hardpan, but do not place the charge so high in the layer that the blast will break through to the surface of the ground without shattering the hardpan to softer ground below.

**CEMENTED GRAVEL** and other tight, bound soils usually lie in layers similar to hardpan, and should be blasted in a similar manner.

Clay soils may be composed of solid clay or the clay may lie in thin or thick layers. Also the clay may be near the surface or may be covered with 1 or more feet of loam or sand. When this occurs, the clay, if less than 4 or 5 feet thick, should be broken through to more open soil beneath. The placing of the charges to do this is precisely the same as in hardpan, as described in the previous paragraph. Where a thin water-tight layer of clay occurs 4 or 5 feet below the surface, the charges should be placed right down on the clay, in order to break it through.

**Loam Soils** the charge should be about 3 feet deep. Loams containing a large amount of fine earthy sediment are benefited by loosening and fining, but the charges should be placed well to the surface—say within 2 or 2½ feet in depth. When the subsoil is heavy, as when of distinctly clay nature, the charges should be placed a full 4 feet deep.

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A typical tree in the orchard of H. M. Magee, Waynesboro, Va. Planted in 1901 in a blasted bed, it began fruiting in 1907, yielding 13½ bushels when 6 years old. The following years its yield was 23/4, 3, 101/4, 12, 14 and 133/4, until 1913. The picture shows the condition of the tree in respect to growth.
Shale and slate surface soils, whether of clay, sand or loam type, often are underlaid with rock. This rock may be brittle and soft, and may be broken up to give more root space. Place charges in the rock as deep as 18 inches below the last of the loose soil. The charges should be heavier than for blasting hardpan.

The amount of explosive to use in each charge must be governed by the depth at which the charges are placed and the hardness of the soil. A strongly cemented hardpan, for instance, will require almost double the charge that is proper for a relatively light soil. Clay, when heavy, requires almost as much explosive to the charge as hardpan, though it shatters under much less force when it verges close on having a loamy nature.

Fortunately, no doubt is necessary about the correct size of the charge for any particular soil, as there is an unfailing rule which determines the correct amount of explosive to use. After you have made sure of the proper depth for the charge by boring or digging into the soil and locating and identifying the various layers composing it, use just enough explosive at this depth to break the ground to the surface without blowing out a crater. The surface of the ground should be heaved and lifted, especially showing a bulge over the charges, but very little of the ground should rise into the air at the time of the blast. When the ground is quite dry the explosion will create considerable dust, which will float above the surface.

The usual charge for blasting tree beds will be about half a cartridge of explosive (1/4 pound) when the charge is located 3 to 3 1/2 feet deep. At 4 feet, 2/4 of a cartridge likely will be required. At 2 1/2 feet deep the charge likely will be only 1/4 cartridge. These figures should be the basis for making the first test shots, but after the tests the size of the charge should be regulated entirely by the results noted, as described above.

It must be remembered that some soils require considerably heavier charges than the above stated ones. It is no rarity to find a hardpan condition requiring 1-cartridge charges placed at a depth of 4 to 4 1/2 feet, and certain hardpan and clay conditions require the placing of 2-cartridge or even heavier charges at depths of 6 feet.

In general small charges are more desirable than large ones for tillage blasting or orchards. The usual method of blasting ground for trees is to place one charge where each tree is to stand.

The trend of practice among those who have studied the matter and have had much experience is to use several light charges placed

A soil auger often can be used to good advantage in making holes for subsoil charges, particularly in heavy soil. Holes started to a depth of one or two feet with a bar can be finished easily with an auger.
not very far apart rather than one large charge, to do the same work in preparing the ground for a tree, or in tilling the ground about one. This is particularly applicable in deep clay and hardpan.

An explosion is necessarily more violent close to the charge. Its fining and crumbling effect diminishes as the distance from the charge increases, hence 3 small charges placed at the corners of a triangle, or 5 small charges distributed over an area about the point where a tree is to be set, will produce a condition superior to one charge located in the center of the area.

The distance between charges is of course governed by the spacing of the trees when only one charge is used in each tree bed. **Spacing Charges** When more than one is to be used for each tree and when the ground between the trees is to be blasted, the charges should be so spaced as to break up all the ground.

When 3 or 5 shots or more are used for each tree or tree bed, the spacing between charges should be 6 to 10 feet. In case of blasting the ground between trees the charges can be spaced 6, 10 and sometimes even 18 feet apart. The only way to determine exactly how far it is best to space them is to dig or probe into the ground after 3 or 4 trial shots. Note how far the crumbling and pulverizing effect of the blasts extend and space the charges accordingly.

In ordinary loam the average properly balanced blast will break as far as 8 or 9 feet away, though the ground at the edges of this circle will not be well shattered. When the orchard is large each charge should be relied on for its extreme range, but in small orchards, particularly in home fruit gardens, where economy in the blasting can be a secondary consideration, the soils should be blasted with charges placed from 6 to 10 feet apart.

The holes should be made straight down. Soil that is dry enough to be blasted offers considerable resistance to a bar or soil auger. Ordinarily the subsoil bar will make **Making Holes** the hole quicker and with less work. In stony land the bar must be used. Sometimes a good practice is to drive the bar down a foot or a foot and a half, or as far as it will go under a few strokes of the sledge, then use the auger for the rest of the depth. When drilling dry ground with the bar, the hole should be filled with water.

The holes should be loaded in the ordinary way, as explained on pages 148 to 150. Put the charge of explosive in the bottom of the hole, push in about 5
Loading Charges

Tamping stick and as you push in more dirt work the tamping rod up and down and close the hole up tight to the surface, being careful not to kink the fuse or the electric detonator wires.

The charges can be exploded with cap and fuse or with a blasting machine and electric blasting cap. When the charges are close enough together to make the breaking overlap at the time of the explosions, it may

Firing Charges

be of advantage to fire them simultaneously, owing to the somewhat greater execution developed. This calls for electric firing. When the charges are spaced so far apart that they will not break all the intervening ground, simultaneous firing is of no advantage. Electric firing involves more trouble than fuse firing, and is considerably more expensive.

Kind and Grade of Explosive

The explosive to use for blasting orchard soil invariably should be a comparatively slow acting one. Since the ground always is dry, no waterproof qualities are required. Use 20% strength ammonia dynamites.

Making the holes in the ground is the big labor item.

Time and Cost

Loading and firing labor is small. One man should make and load 50 to 100 or more holes per day in loam or silt soils in good condition. In certain hardpan soils the same man might make less than 50 holes a day.

The cost of both labor and explosives varies so much from time to time and from place to place that to name a definite figure of cost for blasting orchard soil is risky. The cost, however, ought not to exceed ten cents per shot, on a basis of half a cartridge per charge.

Computation of the average cost per acre is inaccurate, because no two orchards will demand the same treatment. By figuring the cost per tree, or per charge, and using the following table to determine the number of trees or charges in an acre, you can arrive at about what the acre cost in your orchard will be. Nearly every fruit grower knows how many trees he has—knows this when he does not know the exact acreage—and the cost for the whole orchard easily can be figured on the tree basis.

<table>
<thead>
<tr>
<th>Number of holes to an acre, square method</th>
<th>At various spacings, triangular method</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 feet apart</td>
<td>27</td>
</tr>
<tr>
<td>35 &quot; &quot;</td>
<td>35</td>
</tr>
<tr>
<td>30 &quot; &quot;</td>
<td>50</td>
</tr>
<tr>
<td>25 &quot; &quot;</td>
<td>70</td>
</tr>
<tr>
<td>20 &quot; &quot;</td>
<td>110</td>
</tr>
<tr>
<td>18 &quot; &quot;</td>
<td>135</td>
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<tr>
<td>15 &quot; &quot;</td>
<td>195</td>
</tr>
<tr>
<td>12 &quot; &quot;</td>
<td>305</td>
</tr>
<tr>
<td>10 &quot; &quot;</td>
<td>435</td>
</tr>
<tr>
<td>8 &quot; &quot;</td>
<td>680</td>
</tr>
<tr>
<td>6 &quot; &quot;</td>
<td>1,210</td>
</tr>
</tbody>
</table>

It does not cost less to blast tree beds than it does to dig the holes, though the blasting may save some labor. The soil can be shoveled out of a blasted tree bed quickly, but digging without blasting is a slow job. To make the holes for the charges, to load, to fire and to shovel out the dirt, takes about as much time as to dig average holes.
Blasting Soil in Standing Orchards

To blast the soil in orchards already planted, even when the trees have reached full size, is entirely practicable. In fact, this is one of the recognized methods of renovating and improving old orchards.

Precisely the same principles apply to this blasting as to blasting the soil in preparation for planting trees. The only difference is that imposed by the necessity for avoiding the bruising or tearing of roots. The ground must be dry and the charges must be placed at the depth demanded by the nature and condition of the soil.

Ordinarily the best way of going about the work is to put in the ground very light charges (\(\frac{1}{4}\) to \(\frac{1}{2}\) a cartridge of explosive) at the proper depth about the trees under the end of the limbs. Most of the feeding roots likely end nearly underneath that point. Some of the roots within 12 to 15 inches of the charges will be broken by the explosions, but beyond this range they will not be damaged much or at all.

Trees that have been planted only three or four years will have limb spreads too small to come under this rule. To blast the soil about such trees, keep the charges away about 4 to 6 feet from the trunks. Each tree-bed should be blasted with at least three charges.

About large trees the charges should be spaced 8 to 15 feet apart, in order to break all the soil. Possibly the blaster should be satisfied with a little less surface breaking in a standing orchard than an open field or a garden. The correct growing-tree blast will have little visible surface effect. Nearly all of its execution will be confined in the ground 2 or 4 feet underground, or deeper.

It is doubly a mistake to use heavy charges about growing trees. The local effect is too severe. Charges of a full cartridge will break and bruise a good many roots. But the small charges recommended, will not, as a usual thing,
break roots farther than a few inches. Beyond 10 or 12 inches the ground will be loosened and fined for several feet, without any particular hurt to the roots.

The ground beyond the ends of the limbs of the trees always should receive attention. If you thoroughly and deeply work this soil, the new growth of roots will run out to it within a year or two, accomplishing what you are after without much pruning of the root system. The trees in the average orchard are spaced only far enough apart to permit a maximum development of their root systems, hence you should skip none of the ground between.

When blasting the soil under and about large trees, it often is a good plan to blast on two sides of each tree one summer, and on the remaining two sides the following season.

In very poor soils the plan of blasting out deep craters between the trees sometimes is advisable. This serves the double purpose of permitting greater root penetration, improving tilth, and giving a chance to establish a reservoir of plant food and moisture by filling the hole up with manure, commercial fertilizer and mellow top soil, mixed together. The roots quickly will find such a feeding ground. Be sure to include a big proportion of vegetable matter—leaves, grass or straw—with the material used to fill the craters.

The season when tree blasting had better be done is when the ground is dry. The only possible objection to August or September blasting would be that it might force a fall growth. To blasting non-bearing trees in July there is no objection, nor can there be any to blasting after the first frosts have come in the fall and the trees have ripened their new wood. For bearing trees, the blasting should be done as soon as possible after the first frost.
Good Orchard Soil Management

Practical orchardists will ask how correct blasting of soil should be fitted into the regular tillage schedule. The following suggestions do not make a comprehensive outline of the orchard tillage subject, but are intended as a series of more or less connected hints on methods of cultivation.

Trees of any age grow faster when well watered and well fed than when either water or food is restricted. The blasting of soil is designed to increase the supply of both, hence should result in bigger trees at any age. Other things equal, big trees certainly will bear more fruit than smaller trees. They have more bearing wood.

Whether or not the trees bear sooner in blasted ground than otherwise is a matter of condition of the trees when they reach 4 or 5 years of age. If they are growing very rapidly they will not bear well. If they are not supplied with proper nourishment, they will not bear. The trees that bear young are those which have grown vigorously during the first two or three seasons, and then receive some sort of check, but which have good food and water conditions. Lack of moisture in late June or early July may throw the growth of a young tree into making fruit buds. Lack of plant food, summer pruning or insect attacks may do the same. In any case, you cannot get early bearing from trees that are not vigorous, hence to put the soil in condition to produce vigorous trees is a step toward early bearing.

The same soil condition is a preventive of insect and fungus damage to trees, in that vigorous trees will not be overcome by an attack of scale, cedar rust or other orchard enemies as easily as or quickly as one that is growing slowly.

In the case of bearing orchards, the man who blasts the soil has every reason to expect larger fruit than the man who does not. It gives the trees a greater supply of moisture to put into the fruit. The growth, health, and vigor of these trees cannot but be improved by the additional supply of plant food made available, and instead of declining and deteriorating, the trees should become stronger and better each year, unless they have already reached a very advanced age.

The need of intensive deep tillage is greatest when heavy intercropping is practiced in the orchard, and it is under such conditions that soil blasting shows its most pronounced results. This is a western scene, but so far as soil and weather conditions are concerned, it might be anywhere in the country that fruit is grown commercially.
Tilling the Established Orchard

If possible, plan for your blasting some months ahead by sowing a heavy-rooted cover crop in the spring. This is not essential, but it is desirable. Do the blasting in the summer or fall. In July or August, if the spring cover crop has not been plowed down before, turn it down and sow another which should occupy the ground until the following spring.

The use of so many cover crops is advisable because organic matter must be supplied in plenty to the soil if the correct soil processes are to be continued, and a proper condition of granulation is to be brought about and maintained. Blasting or other forms of deep tillage and cover crops go together. Blasting is not half so beneficial without the heavy growth of roots as with them.

In the orchard where the clean cultivation system is practiced, plow as early as possible the next spring after blasting, and keep the ground harrowed every ten days or after every rain until late in June or early in July. Then sow a cover crop again. The surface mulch of loose soil conserves the moisture while the trees need it. The oncoming cover crop takes up the moisture and hastens ripening of soft growth of the trees at the proper time.

The orchard soil should be limed liberally. The best form of lime to use in orchards is the ground raw stone. It should be applied at the rate of 2 tons an acre every 3 or 4 years. The first application should be made during the summer the blasting is done, though it may be given in the spring before, after the ground is plowed for the cover crop.

The use of cover crops is closely associated with the length of time the effects of blasting will last. The deep tillage opens the soil, let us say, to a depth of 4 feet. Unless there is something to keep the particles apart, each winter and each period of wet weather will see more of them floated together into the former compact conditions, but when cover crops are sown the roots go down to the bottom of the layer of loosened ground, and act as lightening to the soil, making it more and more loamy. When practicable, be particularly careful to get a good heavy stand of the cover crop plants close up to the trunks and all about under the limbs of the trees.

If the blasted soil is supplied as it should be with vegetable matter in the form of roots and cover crops plowed under every year, there is no reason why the soil should become compact again for 15 or 20 years. Mere mechanical loosening of the soil, whether with plows or explosives, may not keep it loose nearly so long. Probably under average conditions, it will be well to repeat the blasting every 6 to 10 years.

The kind of cover crop is important only in two respects. You must grow clovers, peas, beans or vetch to get nitrogen. You must grow annual, or bi-annual plants instead of perennials, in order to have dead and decaying roots in the soil rather than living, growing ones. (Weeds, rye, oats, sorghum, millet and many other plants are excellent sources of organic matter).

Any sort of plant will gather and later liberate some locked-up plant food. On this account plants can be called "miners" and "refiners" of slowly soluble plant foods. The fact that they do this is another reason why it is important to have abundant quantities of roots growing deep into the soil.

In grass mulched orchards it is well to plow up the sod every 4 or 5 years in order to force the roots of the trees down from the surface. Otherwise, they will tend to gather just under the grass. The plowing should be done in the fall following the blasting, or the next summer. Soil blasting is especially valuable and beneficial in a grass mulch system of culture.
The fertilizing of orchards under a proper system of intensive deep tillage is a very simple matter. If you grow legumes as cover crops, you will get much nitrogen from the air. Usually, some additional phosphorus, and if available, potash should be supplied. If the trees indicate a lack of nitrogen, by showing yellow leaves and by other signs well known to most orchardists, use a little nitrate of soda, cotton seed meal, or other heavy nitrogen carrier. Lime, of course, is needed, but lime should not be considered as a fertilizer. It is largely a corrective of sourness and a mellowing agent.

**Planting Trees in Blasted Beds**

Shovel out about a bushel of dirt at the point where the tree is to stand. Then with the shovel probe and pry down in the bottom of the hole to see if there is any cavity or pot hole left by the blast. If there is a cavity, pack it full. If the shovel goes in too easily, work it about to compact the ground. Better get in the hole with your feet and tramp the ground a little. If you do not settle the loosened ground in this way, the tree will settle considerably after planting. In case your trees do settle, it is not the fault of the blasting, but of careless planting. The bottom of the hole should be 6 inches lower than is proper for the roots.

Stand the tree in place 6 inches too deep and sprinkle in some fine, mellow soil. Work this among the roots. You have three means of doing it—tamping among the roots with a stick, working the soil in with your fingers, and shaking the tree up and down. The latter is one of the best means, and should never be neglected. In the process of alternate lifting and pushing down, gradually raise the tree the 6 inches and settle it firmly on a well packed layer of earth at the proper depth, which is determined by the dark line about the trunk, an inch below the surface of the ground.

As the dirt fills up about the roots, pack it very hard. Get in with your feet and tramp it till you think the roots will not have breathing space. You cannot well get it too tight. Sometimes a heavy wooden maul or a broad-faced iron sledge is handy for packing the ground about the roots.

The top 3 inches of ground should not be packed. In fact, it is well to go over the planting four days to a week after it is done, with a garden rake, and loosen any crust that has been formed on the ground about the trees by the drying of rain or dew-soaked surface soil. This will prevent waste of soil moisture. At the same time glance along the rows to make sure of the final line-up of the trees.

When the blasting is done in the summer or fall, and the trees are to be planted the following spring, some lime may be sprinkled over the ground with good effect. It is even better to shovel out the loose earth and sprinkle some lime in the bottom of the holes. The lime will help to make the soil more mellow.

Orchard trees should be pruned soon after planting. If they are left with high, heavy tops the wind will work the roots loose in their new beds before they have had a chance to take hold. By cutting back the limbs properly the wind is given less chance at the trunks.
Preparing Charges of Explosives for Firing

A charge of explosives for the purposes of these directions is considered to be all the explosives needed for a single hole with cap and fuse or electric blasting cap properly inserted in the cartridge of dynamite (see pages 143 to 150) and tamped in the hole, ready to fire. The preparation of charges is practically the same for all sorts of farm blasting. The slight variations advisable to suit different kinds of work are not enough to call for separate treatment, since the principles are all the same.

All who use and buy explosives should read the next chapter, beginning on page 152, on the nature and actions of explosives. It is only the man who understands all the facts mentioned there who will be able to load and blast with greatest ease, speed and results.

Scope of This Chapter

It is important for everyone who blasts to understand why he does things, as well as how to do them. For that reason the following discussion of the preparation of charges is made full and complete, with due attention to all the important factors involved. Details of any particular part of the operation can be found quickly by referring to the heading desired, as given in the index.

Readers who may not desire a full discussion are referred to the following brief outline of the process.

Be careful that explosives, cap and fuse are in perfect condition. Cut a length of fuse sufficient for the hole to be loaded, making the cut clean, without dragging ends, at right angles.

Pick a cap from the little tin cap box, carefully, with your fingers, and slide it gently on the end of the fuse. With a proper cap crimper fasten the cap securely to the fuse, making the crimp close to the open end of cap. Avoid twisting or punching the end of fuse against the bottom of cap as well as drawing it away from the bottom. For wet work waterproof the joint of cap and fuse with tallow, soap or other material. Do not use thin grease or oil.

Next punch a hole at a long slant in the side of the dynamite cartridge to be primed. Better use a wooden punch for the purpose. The handle of the cap crimper may be used.

Insert the cap in the hole made as described, tie the fuse in place, and, for wet work, waterproof all openings in the cartridge. You then are ready to load.

Provide space enough in the hole at the proper point to hold the required amount of explosives in a bulk that is not too long. Be sure before you start to press in the cartridges to the bottom of the hole (see pages 135, 148) that there is enough clearance to permit their easy and certain entrance. Tamp fully and firmly up to the top of the hole.

The charge is now ready to fire, which may be done by pressing the burning or flaring head of a freshly scratched match against the powder in the split end of the fuse.

Carrying Explosives and Supplies

The place to keep the explosives is in the magazine or storage place, and not with you in the field. Carry with you in warm weather only enough for the job or the day, or in cold weather only as much as can be kept warm and in condition for firing until you are through loading. Keep explosives separate from caps.

A good way to carry the caps, fuse and small tools is in a basket. Put a piece of blanket in the bottom, to keep
out dampness when the basket is on the ground. Some blasters use an explosives box for the purpose, putting a wood handle or double wire bale on it. The tight wood box probably is a little better than the basket because it affords somewhat more complete protection to the contents.

Whatever the method of carrying the explosives, it should be well protected. This consists in keeping the hot sun off it, keeping rain and fog off it, keeping it away from dampness of the ground, and keeping it safe from meddlesome people and animals.

Many blasters prepare charges before going to the field, but it is better practice to carry along the tools and materials, and to put them together or make the primers on the spot after all the holes are made in the ground or rock, and when everything is ready for the firing except to put the explosive in place.

These remarks are given as reminders. Full discussion of proper handling and storing of explosives can be found on pages 167 to 169 respectively.

Tools and Materials Required

The first step in preparation of charges is to assemble the following: as many cartridges of explosive as will be required; a sufficient number of blasting caps; a sufficient quantity of fuse; some string; a wood punch with an end the size of a cap for about 3 inches; a pair of cap crimpers; a pocketknife. If the holes are very damp or full of water you also will need some tallow or other waterproofing material.

Putting Caps and Fuse Together (Making Primers)

Fuse is described as to sizes and properties on page 166 and caps on pages 165 to 166. Readers who are not familiar with them should turn to those pages at this point. Unroll the fuse and cut off a length that will be enough, since fuse burns about 2 feet in a minute (there are variations—see page 167).

Three feet will give you 1½ minutes or a sufficient time to get beyond danger under ordinary conditions. The fuse, of course, must be long enough to reach out of the mouth of the hole when the charge is in place. Measure the depth of the hole before you cut the fuse.

Warm cold fuse before attempting to bend it. It may be taken into any warm room for the purpose but should be subjected to no heat greater than 110 degrees. If for any reason you have doubts about the condition of your fuse, cut off a foot or more and try it without any cap or explosive. If it will burn properly it is all right.

Be sure to get fresh ends both for the match and to put into the cap. If fuse has been cut for some time into lengths, it is well to cut off short pieces from the old ends in order to bring fresh powder right to the tips.
Cut the fuse off squarely across as shown in the diagram.

The end of the fuse where cut off should be clean and free from dragging ends and threads. If it is not cut off clean, part of the covering may double over the end of the fuse in the cap and keep the spark away from the explosive, causing a misfire. Be careful to keep both ends of fuse off damp ground and out of puddles of water.

If the fuse has been mashed, or is too thick to go into the cap easily, do not peel off any of the covering. Reduce the diameter by squeezing it with the cap crimper or by rolling it on a smooth surface under a knife blade or other smooth implement. Sometimes you can reduce it by rolling it between the thumb and finger.

The very best way to cut fuse is with a combined fuse cutter and cap crimper or on a block of wood with a sharp knife. The blade can be pressed right through the fuse and will make a clean cut. Be careful to avoid twisting, pinching or otherwise knocking the freshly cut end of the fuse about, for you may shake out the powder back far enough to cause a misfire. The powder should come out flush with end.

To get one cap out of the tin box in which they came, tilt the box up on edge till some of the caps slide forward, and then pick the cap up with your fingers. Don't attempt, on penalty of losing a hand, to take a cap out of a box by running a nail or a little stick or the fuse into it in the box. Be careful you do not drop a cap to the ground or floor.

Turn the cap upside down, to make sure there is no dirt in it, and gently slide it on the fuse till the end of the fuse just touches the bottom of the cap. Do not ram, press or twist the end against the bottom.

Hold the fuse with capped end up, to keep the cap from sliding off, and crimp the cap fast. This you do with the special plier like tool called a cap crimper. The "crimp" is made by pinching the open end of the cap tight to the fuse. It should be made within the last quarter inch of the open end of the cap. Never make it toward the closed end because you might disturb the explosive material in the bottom of the cap and cause it to explode.

Crimpings are supplied by all makers of explosives. Order one or more when you buy your explosive. It is well to have an extra one about to use in case you lose one on extensive jobs.

This fastening of the fuse to the cap is one of the points in blasting where a great deal of abuse occurs. Blasters think they can take a chance with danger or with misfires, and attempt to crimp the caps some other way. Except in extreme emergency don't try to crimp a cap with anything except a regular crimping tool; but there are times when one may not have a crimper nor be in a position to wait till one can be purchased. There is a way out of this difficulty—which is to secure a makeshift crimp, with something else than a crimper. It is possible to use a pair of pliers, or a small pair of pincers, and accomplish something that may hold the cap on the fuse. The best makeshift
crimp is to take a fold of the cap up at one side of the mouth with a pair of close fitting, square-nosed pliers. Be careful while doing this that you do not grind the end of fuse against the bottom of cap, or pull the end back from the bottom. If the fuse should pull away from the bottom of cap a quarter inch, a misfire likely would result.

Waterproofed [tallowed] cartridges ready for loading in wet holes.

When the charge is to be placed in a dry hole, waterproofing is not needed, but in a wet hole the connections between fuse and cap must be made water-tight with tallow or soap. Do not use waterproofing grease, because it may unite with the tar in the composition of the fuse cover and soften it, when the powder train will be ruined. Water in the cap will surely make it worthless.

Inserting Caps in Explosive

The best location for a cap in a cartridge of explosive for farm blasting is in a hole in the side, about an inch and a half from one end. The best position for the cap at this point is at a slant that takes it in from the side toward the center, but as near longways, or parallel with the sides of the cartridge, as possible.
In cutting fuse from roll use sharp knife.

Taking one cap carefully from box.

Inserting fresh end of fuse in cap.

Crimping cap with the cap crimper.

Fuse tied firmly to cartridge with string.

Electric Blasting—Pass the doubled fuse wires through a hole in cartridge.

Loop the doubled end of fuse wires over end of cartridge.

Pull loop tight, bend wires at cap, punch hole in top of cartridge.

Insert cap in hole, take up slack in wires. (Waterproof holes if ground is wet.)
Position of Cap in Cartridge

In other words, when making the hole for the cap in the explosive, make it with as long a slant down toward the other end of the cartridge as possible. There are reasons for this connected with superior or inferior detonation.

Another method of priming much used is to insert the cap in a hole made in the end of the cartridge of explosive, and then to tie the paper about the fuse or wires. This is good so long as it is not damaged, but care must be exercised not to have the tamping stick interfere with fuse or cap. With side priming there is a cushion of the soft explosive between the end of the cartridge and cap. End priming always is good provided sufficient care is taken in loading to prevent disturbing or displacing the fuse or cap with tamping rod.

When all the explosive is removed from its wrapper, the cap must be inserted in the loose explosive. This should be done by making a hole, as in a cartridge. But it seldom pays to take all the explosive out of its wrapper. Nearly always you can leave a half cartridge of explosive intact for the cap.

![A good crimp.](image-url)

To make the hole for the cap use the handle of the cap crimper or a wooden punch just a little larger than the cap. The hole should be large enough to let the cap in without much pressing, but should leave no air space about the cap. The depth of the hole also is important. It should be just enough so that the entire cap can be buried in the explosive, but not any deeper. If it is deeper, the cap may be forced down to the bottom, which will leave some of the fuse in contact with the explosive (which may cause burning instead of exploding of powder), or the cap may be seated just inside the wrapping, leaving an air space at the inside end or bottom of the hole, which may lower the effectiveness of the explosive.

When the cap is seated in its hole in the side of the cartridge, the fuse will extend up along the cartridge past the near end. It must be tied in this position, so securely that the fuse and the cap will not be pulled back in handling or by rubbing against the side of the hole when the cartridge is pressed down. The best way to secure it is to wrap a strong string several times below the point where the cap is inserted, then give two or three wraps about the fuse, and pull tight and tie; or take two loops about the fuse and then several wraps about the cartridge.

![Cutting cartridge in two—roll it under knife blade.](image-url)

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When the foregoing directions have been complied with you have a cartridge of explosive primed with a cap and fuse. It is ready to put in the bore-hole in the rock or ground.

Loading Charges in Holes

You will need a tamping stick. This must be of wood, and had better be about the size of a cartridge of explosive, which usually will be 1\(\frac{1}{4}\) inches in diameter, except in case of blockhole blasting of boulders, when a smaller cartridge sometimes is needed to go in small drill holes. Never use a metal rod for tamping. Make sure that the hole is ready. It must be big enough to allow cartridges to slide down easily (except in the case of small holes drilled in rock, when the explosive all must be taken out of the Tamping Rod wrapping and crumbled and pressed into the hole). Loose stones, sharp stones and roots that obstruct the hole should be removed with a bar or spoon scraper. This work must be completed before starting to load. If obstructions fall into the hole, after some of the explosive is in place, don’t try to remove it by force. Make another hole at a safe distance from the first, put in another charge and fire it.

Measure the hole with your tamping stick and judge if there is space for the required charge at the right point. Nearly always a charge of explosives should be as compact as possible. If one or 2 cartridges are all the explosive required, it usually will not hurt to put them end to end. But if 3 or more cartridges are required, to put them end to end makes the charge too long, and places the force of the blast elsewhere than where it should be.

When your judgment tells you that the charge should be in a more or less round bulk, enlarge the hole at the point where the charge should be made. Sometimes this can be done by scraping it out at the bottom with a toe-bar or spoon-bar. Again, if much enlarging is required, it is well to use a small amount of explosive to secure it. This is called springing. To do this prime about a quarter of a cartridge as usual, and push it to the bottom of the hole. Use no tamping. After it is fired wait till the hole cools, and you will find a cavity large enough for your full charge.

It is better to avoid springing holes if you can, on account of the fact that the cavity often is enlarged too much, and the surrounding earth is loosened so much as to injure confinement. (See page 156 on detonation). A great deal can be done by scraping the small auger hole out to 2 or 3 inches in diameter at the bottom and then causing the
cartridges to enlarge and fill the hole solidly. To accomplish this enlargement of cartridges, slit their wrappings 3 or 4 places lengthwise, from end to end. Then press them home with the tamping stick. They will expand and shorten. Four to six cartridges in this way can be got into the full length of two.

Still another way is to take the explosive entirely out of the cartridge wrappings, and with the help of a tin or paper tube, such, for instance, as calendars are mailed, funnel it down to the bottom of the hole. But neither this method nor slitting the cartridges is wise in wet holes. It is true that nitroglycerin powders will stand considerable water, but the safe rule in wet blasting is to leave the cartridges intact. Ammonia dynamosites will not stand wetting inside the paper of the cartridges without damage. (Never under any circumstances cut, break, unwrap or punch holes in explosive that is frozen. You invite an explosion in your hands when you do.)

When there is more than one cartridge in the charge, place the primed cartridge on top of the others—put it in the hole last or next to last—when using the cap-and-fuse method of firing.

Be sure that all parts of the charge are in firm contact. It will not do to have air spaces, or dirt, or wrinkled paper between the cartridges. While all the powder likely would go off under these conditions, it will not do as much work as it should.

The cartridges of explosive may fit tightly in the holes. In that case do not ram or pound them, but press firmly against them, one at a time, with the tamping stick. Press the explosive into tight contact with the sides all round, at the bottom of the hole.

**Tamping**

Tamping is a necessity and one of the most important parts of the operation. The charge should be tightly confined. It is only in springing holes and sometimes in digging post holes that no tamping is advisable, and in ditching that the quantity needed is less.

When the explosive is in place at the bottom of the hole, start the tamping by rolling in some loose ground. Keep the tamping stick working up and down to seat this ground against the explosive, though make no effort to get it tight till there is a few inches or so over the explosive. An exception to this rule is in the case of blockhole blasting of boulders and ledges, when damp clay tamping should be packed solid all the way down to the explosives.

If the tamping is less than this, the best results will not be secured, hence deep holes often are necessary for the sake of confinement of charge as well as to contain the amount of powder used.

Hold the fuse to one side with one hand while the tamping stick is worked with the other hand. Rake the dirt to the mouth of the hole and be careful to get in the hole only earth—not clods, sticks, grass, etc. Be very careful not to damage the cover of the fuse with the tamping stick.

Fill the hole to the top with tamping, and make it tight. The best material for tamping is moist clay. Tamping material always is better when made wet enough to ball. Use the heaviest earth within reach, and if it is dry, moisten it.

**Firing**

The free end of the fuse will stick out of the hole filled with tamping, say about 4 inches. Your remaining work is to set fire to the powder in the
fuse, till it begins to spit continuously. Split the end of fuse with your pocket knife to make it light easily. Put the flaring head of a freshly scratched match against the powder exposed by the cut. (See page 159.)

Preparing Charges for Electric Firing (Making Primers)

Up to this point in the directions for preparing charges the text has spoken only of caps and fuse. When the firing is to be done with an electric blasting machine instead of fuse, you must use electric blasting caps.

These come from the makers with the wires already fastened in them. (See pages 165 and 166.) They are ready to be inserted in the cartridge of explosive without any preparation such as ordinary caps and fuse require.

Make a slanting hole in the cartridge of explosive just as is described on pages 145 to 147. Into this insert the electric blasting cap, letting its wires project just as the fuse does when fuse is used. Then tie the wires to the cartridge with a string as fuse is tied, to prevent the cap from being pulled partly or entirely out of the hole.

It is a little difficult to tie the wires tight enough with a string to prevent slipping. Another way to fasten them securely is to punch a hole from the center of the end of the cartridge in a slanting direction so that it will come out at the side two or three inches from the end. Bend back the electric blasting cap wires about eight inches from the cap and insert the loops of the doubled-over wires in the hole in the end of the cartridge, pushing it out through the side. Open out the loop in the wires and pass the loop over the other end of the cartridge. Punch another hole in the end of the cartridge a trifle to one side of the first hole and straight down toward the center of the cartridge. Insert the electric blasting cap in this hole and then take up all slack in the wires. The result will be a primed cartridge where the wires do not cross each other at any point and the electric blasting cap is lying parallel with the center line of the cartridge. A cartridge so primed hangs vertically so that it is possible to load it in a vertical bore hole without its lodging against the sides. See page 146.

In fixing wires of electric blasting caps to cartridges, avoid crossing them and avoid bending them sharply or in any manner that will break their insulation. If the insulation is broken it likely will cause a short circuit, which will result in a misfire. *Never take a half hitch about the cartridge with the wires.* Do not pull at the wires and the cap, because to do so may break the fine bridge wire that causes the cap to explode when the current goes through.

Load these primed cartridges the same as is directed for fuse primed charges. Be careful to avoid rupturing the insulation on the wires with small stones in the hole or with the tamping rod.
The finishing of the tamping leaves two wires projecting from each hole. They must be connected with the blasting machine or other source of current with connecting wire and leading wire, in the manner described fully on pages 161 to 164. Further discussion is not needed at this point.

Some General Suggestions

In priming cartridges of explosive with fuse and blasting cap, you must be careful to avoid permitting the fuse to touch the explosive. High explosives will burn like gasoline or coal-oil. They are very easily set on fire by sparks spitting from fuse. When they are burning the explosion will be very much weaker than it otherwise would be, and will give off noxious gases.

A very frequent cause of misfires is the bending, kinking and crooking of fuse. This is especially frequent when the cap is inserted in the center of the end of the cartridge of explosive and then carelessly forced over against the side of the hole by the tamping stick and tamping material. Keep the fuse straight, and never under any circumstances lace it through the cartridge of explosive. That is a sure cause of trouble.

If it becomes necessary to remove a cap from a primed cartridge of explosive, do it gently and carefully, and unless the cap and fuse are immediately to be inserted in another cartridge, destroy them both by lifting a shovelful of earth and putting the cap under the ground in the hole, after which light the fuse and go away.

It is better not to lift or carry the primed cartridge of explosive by the fuse or wires when it can be helped. When a practice of carrying primed cartridges by the fuse is made, misfires and poor explosions will be caused, not every time, but often enough to make it wiser not to do so. The cap often is pulled back in spite of the tie string.

Where explosives that are subject to water damage are used in work that is wet, matters can be helped by making the cartridges waterproof with tallow, paraffine or other suitable material. It is practicable to stop all the seams on the cartridges, load and fire without delay, even with explosives that would be put out of business if the water got at the actual material instead of only at the wrappings of the cartridges. Pay particular attention to waxing or tallowing the place where the cap and wires enter the cartridge.

When doing wet blasting, use every care to keep the outer end of the fuse from dropping into the water or from resting on damp ground. The inner wrappings of fuse and the powder train itself take up water like a blotter. On a very foggy day it is well to keep fuse in a closed box. Mist and rain, of course, will damage it.
Explosives and Blasting Supplies

The catalogs of manufacturers are not intended to give all the fundamental facts about and the differences between the various explosives. To do so would take too much space. They give the trade names and the measurements and weights of cartridges and boxes, demanded by purchasers, and are prepared on the supposition that blasters and buyers of explosives know what they need. This bulletin includes explanations of the names under which blasting explosives are made and marketed, outlines their properties, and makes clear the work and conditions for which each grade is intended and suited.

Explosives

There are scores of different kinds of explosives made and used for blasting purposes, and many dozens of different names used for them. The most familiar name of any explosive in America is dynamite. Other names are farm dynamite, quarry powder, contractor’s powder, coal powder, stumping powder, Judson powder, gelatin, blasting gelatin, R. R. P., giant powder, blasting powder and dozens of others.

Nearly every one of the explosives designated by these names is made in several strengths, and in qualities to suit varying conditions. For this reason figures and other marks are attached to the names to distinguish the grades. In addition to this some of the names are used to designate not only one certain explosive but several widely different ones. This is particularly true of the names dynamite and powder. The selection of names in the preceding paragraph is made for illustrative purposes, and is not to be taken in any sense as a recommendation of those explosives for any purpose. The recommendations are given in detail on other pages.

All blasting explosives are not made from the same ingredients, and they differ a great deal in many other ways than in quality, as quality is generally understood. You can buy cornmeal that is good, bad or indifferent, but when you buy explosives you will find there are few which can be classed as of poor quality. Nearly every standard kind and grade is of excellent quality for some particular purpose and condition. And practically every one can be classed as of poor quality for conditions and purposes to which it is not suited.

Nor is the difference one of size of cartridge or grain, as the case may be, though this is one element. The main differences are ones of strength, quickness or speed of gases, sensitiveness, resistance to cold and to water, density, fumes and cost. Some explosives are suitable for wet work, and others only for dry work; some are adapted to blasting hard, tough rock, others to blasting ground only; some freeze when chilled a little; others can be exposed freely without freezing. And it should be noted that many of the better explosives of to-day have been developed during recent years and are comparatively new. The explosive to buy for any particular work is the best one on the market for all the conditions involved.

Black blasting powder has been known and used for several hundred years, and it is practically the same to-day as it has been for a long time. It is composed of saltpeter or nitrate of soda, sulphur and charcoal. It does not vary in strength, and varies little in other properties.

Explosive Ingredients

The dynamites and high explosive powders have little or no relation to black blasting powder. They depend for their explosive force on other explosive chemicals the best known of
which are nitroglycerin and ammonium nitrate. It is not necessary in this brief description to name additional explosive elements.

The first dynamite was made in Europe by mixing nitroglycerin with a light spongy earth, and packing the mixture in paper tubes as cartridges of dynamite and powder are packed to-day. Nitroglycerin itself is a wonderfully efficient explosive when it can be controlled, but it is so sensitive to shock that it must be mixed with absorbents and treated to make it safe enough to handle.

As other explosive chemicals become better understood, it has been found of advantage to substitute materials that are explosive for the light earth used to absorb the nitroglycerin. And more than that, the nitroglycerin itself has been displaced to varying degrees in some of the dynamites by ammonium nitrate and other materials. Few blasting explosives contain no nitroglycerin at all, but many contain only 4 or 5 per cent. of it. Each of these combinations of materials, or formula, has its own peculiarities in addition to variation in strength, all of which information it is well for a buyer and blaster to understand.

The explosives marketed as “straight dynamites” are made from nitroglycerin. Those made from an ammonium nitrate base are called by many manufacturers “extra” dynamites. Gelatin dynamites and blasting gelatin are nitroglycerin explosives in which the nitroglycerin has been combined with gun cotton. The various special mine, quarry, stumping, farm and other miscellaneous dynamites and high explosives on the market are not so named that their ingredients can be determined without a statement from their makers.

The power of an explosive and its violence are two different qualities. The power, or direct strength, is due to the volume of the gases. If a pound of a certain explosive gives, for instance, 1,000 cubic feet of gas when completely detonated or fired, while a pound of another explosive gives 500 cubic feet and a pound of a third gives 2,000, the lifting power of each explosive will be in direct proportion to its gas volume.

But the violence of the gases depend, not on their volume, but on their speed. If they are comparatively slow in forming and in forcing their way out of their confinement they will break out large cracks and escape through them, pushing the material aside. If they are very fast or quick, they will grind and pulverize everything they come in contact with, and throw out the whole side of the confining material, but will not crack it so far.

The matter can be made clear by comparing a push with a blow of a hammer. Both may have equal power, but the effects on a block of wood, for instance, at the point where they are applied are very different. The push will move the object almost without marking it. The blow may move it, but it is sure to leave a mark of greater or less depth, depending on the nature of the hammer and its speed. A still better comparison, perhaps, is that between the blow of a sledge and of light hammer. It is possible to hit a blow of as much power or weight with one as with the other, but the material at the point where the blow lands with the light hammer will be badly dented, or maybe broken. The reason is that the light hammer moves with much greater speed.

In quarries blasters make use of these facts in order to get the rock broken out in pieces of the size preferred. When they want large pieces they use an explosive with sufficient power to break the rock, but, comparatively speaking with a slow speed of gases; when they want small pieces and much shattering, they use an explosive of the same or greater power but with swift and violent gas action.
For each result and for each material a certain power is required and a certain quickness of the gases is best. By way of illustration, take soil blasting for tillage purposes. There is no object in violently grinding the earth at one spot while surrounding earth that might be reached is left untouched. A proper explosive for this purpose is one that will have enough pulverizing action, that will lift and shake up the soil, and that extends its effects for long distances. For an example of the other extreme, take mud-capping rocks. For this work the explosive cannot be too violent in action. The gases, backed up by the rapidly yielding wall of air behind them, must strike the rock a crushing blow in the minimum of time.

Nitroglycerin and ammonia dynamites, for all practical purposes, are of equal strengths when of equal markings. The strength is indicated accurately by percentage figures.

Nitroglycerin explosives are uniformly quicker and more violent in action than ammonium nitrate explosives, and the more nitroglycerin there is in the explosive the quicker it is. The ammonia explosives are not as quick, in any strength, as the corresponding nitroglycerin explosives. Therefore a 50% nitroglycerin dynamite is more violent than a 50% ammonia dynamite, and a 20% ammonia dynamite is much less violent than a 50% grade.

When the object is to shatter and reduce to fine fragments the material to be blasted, the proper explosive is a quick one, while when the object is to lift and shake up the material the best explosive is a slow one. (See table on page 156, also detailed recommendations on pages 136, 152 and 156.) But there are other factors that must be considered.

Nitroglycerin explosives resist water better than ammonia explosives, but if the cartridge wrappings are not broken or opened, ammonia dynamite or powder can be loaded in wet holes with entire satisfaction. The firing should not be delayed any longer after loading than necessary, and it is wise to plan the work so that it may be done at the longest within a half hour after loading. Storage in a damp place will weaken explosives, especially ammonia explosives.

Gelatin explosives resist water very well, and may be loaded in wet holes, or under water, with assurance that they will explode with their full power. Blasting gelatin is entirely water-resisting.

Explosives will freeze, and when in this condition are dangerous, and cannot be fired properly, if at all, with a cap of any kind. They must be thawed and they must be handled very carefully if they are to be used. On no account attempt to cut the wrappings, to break a cartridge or to handle the frozen explosive in the ordinary way. (See pages 157 to 159 for directions for thawing.)

Regular nitroglycerin explosives are quickest to freeze. Others, known as “Low Freezing,” will stand much lower temperatures without causing trouble in this respect.

Freezing  Ammonium nitrate explosives also will freeze, but not quite so quickly as nitroglycerin explosives. They too are made on both regular and low freezing formulas. The low freezing ammonia will stand more cold than the low freezing nitroglycerin.

The regular explosives will freeze at temperatures of 45 to 50 degrees. The low freezing explosives will not freeze and become solid till the thermometer gets down below the freezing point of water, and in practice many of them can be used right out in the open when the temperature is down to 32° F. for some time before starting to freeze. The length of time the powder is exposed to the cold has much to do with its freezing.

The safety point for both low-freezing explosives and regular explosives is not a matter of rule, but of watching the explosive. When dynamite is frozen,
the cartridges will be hard, and when it is partly frozen they may have a mottled appearance on outside of the paper wrappings. The hardness may only be in spots. When not frozen, the cartridges should be a little soft all over. No explosives should be handled much, cut, punched, rubbed, broken or loaded when they are frozen. They cannot be exploded satisfactorily and such acts are dangerous.

In cold weather always use the low freezing grade of explosives, for the regular grades may freeze in the holes before they can be fired. It is a good plan to use the stronger caps, say No. 8 (see page 165) in cold weather. When a charge of explosive is chilled but not frozen it can be fired satisfactorily by a heavier impulse (blow and heat) than ordinary, such as a fresh No. 8 cap gives. The low freezing explosives do not differ in action from the regular explosives, and are just as efficient.

The gases of explosives naturally are more or less objectionable when breathed. Some of them are poisonous, others are merely disagreeable. When explosives are used out in the open the gases are taken up by the air so quickly that none of them give any serious trouble, though they do cause headaches if the fumes are inhaled. It is only in tunnels and deep shafts where the air is confined that the matter of fumes is important, not on farms.

Special explosives have been developed for tunnel and mine work, but they are not important in agricultural work. The only fact about fumes worth knowing in farm blasting is that nitroglycerin explosives either in the form of their gases or when absorbed through the skin will cause headache somewhat quicker than ammonia explosives. The so-called fumeless explosives always cost more than any ordinary dynamites and are not suited to farm work. Farmers will do well to buy grades of explosives suited for their special purpose.

Most dynamite is a light-colored material that looks like fine, sticky sawdust, and it is packed in “sticks” or cartridges made with cylinders of tough paper. These cartridges vary in diameter and length. The standard is $1\frac{1}{4}$ inches in diameter and 8 inches long. This is the size carried in stock by dealers and in the magazines of the makers. Sizes other than the standard $1\frac{1}{4}$ by 8 inch may cost more per pound than the standard owing to higher packing cost.

Dynamite is usually packed in wooden boxes containing 25 pounds or 50 pounds. A 50-pound box of 20% ammonia dynamite will contain about 100 $1\frac{1}{4}$ by 8-inch cartridges. If of 20% nitroglycerin, it will contain about 98 cartridges. If of gelatin dynamite, it will contain about 88 cartridges.

A word should be said here about the cost of explosives. No quotations can be given because the prices vary in different parts of the country and from time to time. The ammonia products usually are cheapest. The cost of course follows the percentage strength, the low percentages cheaper and the high percentages dearer. Gelatin explosives cost about the same as straight nitroglycerin explosives. The special explosives for use in mines, tunnels, quarries, railroad construction work, etc., often cost more than the explosives recommended here for farm work.

In buying explosives look first to getting the one that is best suited to the work to be done, and aside from that the cheapest one. There would be no object in using a straight nitroglycerin or a gelatin explosive when one of the ammonia farm powders would do the work, for the former explosives cost much more than the latter.
To avoid "explosive misfits" it is well to consider carefully the nature of the material to be blasted, the conditions of weather, water, etc., and the results wanted. The kind of explosives to use depends on these factors. Keeping in mind the facts mentioned in preceding paragraphs, the reader will see that there is a type of explosive made for almost every condition and kind of work, and will understand why one will not suit the work of another.

As the briefest and clearest way of giving general suggestions for the type of explosive best for different agricultural work, a table follows: (Detailed recommendations are given on pages 136 and 152.

**Explosives Recommended for Different Work**

Stone blasting—mudcap .......... Straight nitroglycerin or ammonia dynamite, 50% or 60%.

Stone blasting—undermine "Snake holing" ........ To break, same as for mudcapping; to throw out, use any dynamite of 20% strength.

Stone blasting—blockhole .... To shatter well, any high percentage dynamite; to break into large pieces, 20% ammonia dynamite.

Soil blasting—for subsoiling and for tree planting .......... 20% ammonia dynamite.

Ditching—electric firing .......... 20% to 40% ammonia explosives; (nitroglycerin is equally effective); in loose dry ground, high percentage nitroglycerin explosives.

Ditching—transmitted detonation .......... Straight nitroglycerin dynamite, 50% or 60% strength.

Stump blasting—in medium and heavy soils, wet or dry. 20% or 30% nitroglycerin or ammonia dynamite.

Stump blasting—in dry sand and other light soil .......... 40% or 50% nitroglycerin or ammonia dynamite.

If you are in doubt as to the best explosives for your particular work it is well to write to the manufacturer you prefer, asking which of his grades and brands would be most suitable.

**Detonation**

It is well known that black powder is fired by a spark, and that dynamites and high explosives cannot be fired by a spark but require a combination of shock and heat such as is produced by a detonator. It is not so well known that there are great differences in the nature and effect of the explosion of any dynamite, due to variations in the way it is fired.

An explosion of dynamite is the result of a very sudden creation of a great volume of gas from a smaller volume of explosive. The kind and amount of gases produced by any high explosives depend on the kind and amount of shock used to fire the charge, and on its confinement.
The effect of lighting a piece of unconfined dynamite with a piece of fuse without a cap on, is that the dynamite will burn fast without exploding and make a dense smoke which has a bad smell and produces severe headaches. This is simple combustion. If the piece of dynamite is confined closely and lighted in the same way it will explode, but will give off similar bad fumes. If a weak cap is used on the fuse, or the dynamite is set off by a fall, the dynamite will be partially detonated, and explode with considerable force, but it still will give off the bad fumes and smoke. The same piece of dynamite fired with a No. 6 or 8 cap will be completely detonated, and will explode with great violence and force, even when unconfined, except by air, and will give off very little smoke.

The last-named explosion is detonation. It is produced by a violent shock in connection with intense heat. Nitroglycerin is 5 times as strong as black blasting powder when exploded by fire, and 10 times as strong when detonated. This explains the enormous force given by detonation as compared to simple explosion.

But detonation itself is no set thing that always takes place the same. There is good, or complete, or full detonation, and there is partial detonation. In case of incomplete detonation, or any detonation at a less speed than the greatest for any particular explosive, the gases formed are not what they should be. For one thing, they are more noxious or poisonous. The more powerful and severe the blow delivered by the cap, the more quickly does the chemical action take place in the explosive. It is only when high explosives detonate with their greatest speed that their maximum power is generated.

Air spaces about the cap in the cartridge of explosive cushion its blow and weaken detonation. It is the nature of the initial detonation of the powder right around the cap which governs the nature of the explosion of the whole charge. A blaster should understand the importance of setting up complete detonation in order to get the greatest amount of force out of explosives. Sometimes explosives lose as much as 20% of their effectiveness when fired with weak caps. Lack of confinement has a similar effect. Sixty per cent. dynamite poorly detonated is less effective than 40% well detonated.

When explosives become chilled it is difficult to detonate them properly with the usual cap, hence the advisability of using a very strong cap in cold weather—a No. 8. Many of the holes are frequently loaded for some time before firing, and even if the powder is soft and normal while charging, it afterwards becomes somewhat chilled in the cold ground.

Throughout this and other bulletins in this series, the terms caps and electric blasting caps are used in speaking of the exploders used to fire the charges of dynamite, although in the field and among manufacturers the same articles are called by the terms “detonators,” or “electric exploders,” or “electric blasting caps.”

**Cap Means Detonator**

**Thawing Explosives**

It has been pointed out (on page 154) that regular explosives chill or freeze at temperatures of 45 to 50 degrees. With the increase in the number of low freezing explosives that seldom need thawing, the necessity for doing the thawing on farms is not as frequent as it used to be.

Cartridges of frozen dynamite improperly handled are dangerous materials, and whenever the temperature is near the freezing point for them, the cartridges
should be inspected before using to see if they show any of the hardness that indicates chilling. If so, handle them very carefully till they are thawed. Dynamites will be a little soft to the pressure of your thumb when they are not frozen.

**Frozen Explosive**

Frozen explosives are dangerous because they are very much more easily exploded in the course of ordinary handling. They are more sensitive to friction and to blows of tools. The cartridges may explode when broken in two, when wrappings are cut with a knife, when cap holes are punched with a stick, or when they are shoved into a hole with a tamping stick. At the same time they are so much less sensitive to the direct shock of a detonating cap that they cannot be fired properly with a cap. Therefore the rule must be laid down that frozen cartridges of high explosives never must be cut or ruptured or used until they are thawed.

When nitroglycerin freezes it crystallizes, therefore the nitroglycerin in dynamite tends to separate from its absorbing materials into small crystals. When the dynamite is thawed slowly with cartridges lying on their sides, the nitroglycerin is reabsorbed as fast as it liquefies. But when thawed too fast, the nitroglycerin is liable to run out of the cartridges before it is reabsorbed. Quick thawing will damage explosives a great deal more than they would be damaged by freezing followed by long, gradual thawing.

Thawing is a dangerous operation when not done right. It probably is correct to state that more accidents with dynamite have occurred in the course of improper thawing than for all other reasons put together. At the same time proper thawing is entirely safe.

Two of the most frequent causes of accidents while thawing explosives are in putting the cartridges into water or steam, and putting them on hot stoves or stones. Water, and especially hot water, forces the nitroglycerin out of the cartridges. The free nitroglycerin goes to the bottom, and explodes at the time of the first increase in heat, or first light blow. When cartridges of dynamite are laid on hot material the nitroglycerin also runs from the paper wrappings and drops of it fall to the stone or metal. This almost always causes an explosion. At about 350 F. degrees of heat, which is only a little more than that of boiling water, the nitroglycerin will explode without a shock.

Examine your explosives a day or so before you are ready to use them, and if they show that they are frozen, proceed to thaw them in one of the following ways: Use only a **DRY** warmth.

**Safe Thawing**

Use no temperature higher than is comfortable to the hand, or the limit may be set at 100 or 110 degrees. Use no heat of any kind that cannot be controlled with certainty. If you do this you will be safe.

Every large maker of explosives will supply thawing apparatus that is safe. Sometimes this is a double kettle arranged so that the cartridges of explosives can be placed in the inside vessel, while the outside vessel can be filled with warm water and a blanket can be spread over the top. Other more elaborate thawers consist of a vessel containing watertight tubes just big enough to hold cartridges of explosive, running through a space to be filled with warm water. The catalogs describe these ready-made thawers in detail.
Home-made thawers can be arranged with two buckets, one small enough to hang inside the other. Put the cartridges inside the small one and warm water around the outside, in the big bucket. Another good way is to put a five-gallon can of warm water inside a barrel, or box, and pile the cartridges of explosives in the barrel around the can. The top of the barrel should be covered with a blanket. Or put the water in the barrel and the explosives in a can or bucket. A small closet of course can be used instead of a barrel. A can of warm water can be set inside a magazine to keep the temperature up.

The old-fashioned manure pile method of thawing is reliable and safe. This consists in burying a box somewhat larger than a box of explosives in fresh horse manure, and placing inside it the box of explosives to be thawed. A foot or more of manure must cover the box, and a small pipe or tube should be inserted for ventilation. The manure must be fresh. Allow at least 10 hours to thaw a box of dynamite in this way. Twenty hours is better.

The box of explosives can be taken into any warm place that is dry, but if this is a building you must take your own risk of fire and accident. Watch the box and the cartridges to see if the freezing and thawing causes the cartridges to leak free nitroglycerin. If any of this leaks out of the cartridges and gets on the floor it must be washed up according to directions in paragraphs on storage. (Pages 168 and 169.)

The cartridges of explosives had better be piled irregularly rather than in tiers, for thawing. They will rise in temperature quicker in this way. They always must lie on their sides rather than stand on end.

Electric and Fuse Firing

The very best way to light fuse is to split the end for an inch or less, and stick the burning head of a freshly scratched match right against the exposed powder at the head of the split. This will light the fuse even in a strong wind.

Where there are very many fuses to light in succession, as in subsoiling, it sometimes is of advantage to use a gasoline or other torch, holding the hot flame under the fuse for an instant. Whatever the method, do not leave till you see the fuse spitting sparks and smoke swiftly and regularly. Further discussion of fuse firing, except as to its adaptations, is not needed.

Farmers who have only a few stones or stumps to blast, or who are planting a few trees or doing a little subsoiling, Electric Firing will not need any other method of firing than by caps and fuse. Ditch blasting in ground not watersoaked demands electrical firing, while the blasting of large stumps, particularly if green, and in sandy soil, as well as the blasting of large rocks, is made easier, safer and cheaper by electrical firing. For large amounts of almost any blasting except that of tree beds, subsoiling and very small stumps and isolated small boulders, the purchase of an electric blasting machine and the necessary wires is justified by the advantages of the electric methods of firing.
The primary reason for the superiority of electric firing over fuse firing is that several charges may be exploded at once; the different charges will increase the efficiency of each other. Thus in ditching, you can fire many charges in a row and make a perfect ditch. In stump blasting several small charges very often will take a stump out better than one large charge, and in orchard, and garden subsoiling the simultaneous blasts frequently are of advantage.

Electric firing is more certain when the charges are under water. The danger from misfires due to moisture as well as from some other cause is reduced. Should misfire of the electric blasting cap occur, you are safe in going to the charges as soon as the wire is disconnected from the blasting machine. With a fuse you must wait some hours to be safe. When several charges, as for instance, several boulder blasts are to be fired, you can make one trip to safety do for the lot, instead of having to travel back and forward for each shot. The greater safety of electrical blasting is due to the fact that the time of firing a shot is under the control of the blaster. Finally, the intelligent and careful use of electric firing, with its possibilities of two or more small charges doing the work of one large one, and its other economies, will save considerable explosives.

All the makers of explosives supply electric blasting machines. The machines are small boxes of wood or metal, containing a small dynamo with a handle that you either push down or twist, depending on the type of machine, to operate and to fire the charges.

**Electric Machine**

The machines are made in various sizes and capacities to fire 3, 10, 30, or more charges at once. The 10 charge machine weighs about 15 pounds. Full directions for operating and caring for the machines always accompany them.

For electric firing, in addition to the machine, you will need electric blasting caps, possibly connecting wire and leading wire. The leading wire is copper wire large enough to carry the amount of current required for the number of charges to be fired simultaneously. It is covered with insulating material, and is made strong and durable to stand much use. To make the circuit from the blasting machine to and through the charges and back again, you must have two strands of leading wire. It comes from the
explosive makers in single-strand form, which must be doubled, and in what they call duplex form, which has two strands of insulated wire twisted together or wrapped together under one cover.

The two small copper wires that are fixed in the electric blasting caps (see pages 165 and 166) should be long enough to reach out of the holes. They may be bought in a variety of lengths, but 4 or 6 feet are regarded as standard. If the charges are close enough together so the wires can be connected, no connecting wire will be needed; but whenever the distance between is more, the charges must be connected, and connecting wire is the right thing to do it with. There is no particular limit for the distance between charges that may be connected for firing together.

Good connection for electric cap wires.

Good connection for small cap wires and large leading wire.

Don't Connect This Way

A very bad connection—a cause of misfires.

The diagrams in these pages will show how to make electric wire connections. Cut away the insulation on the wire ends and wrap the ends together tight. Wrap them for two inches. Looping the wires will not do. Be careful to scrape with a knife or stone the wire ends to make them bright before wrapping them together. Corroded or dirty connections are a cause of misfires.

Wire Connections

If the leading wire gets broken and must be spliced, solder the connection after wrapping the ends together, then wrap the joint with tape to
insulate it. Ordinary tire-tape is good, but a better way is to wrap the joints with special rubber tape underneath and to cover this with the tire-tape.

When only one charge is to be fired, connect the ends of the 2 strands of the leading wire to the 2 electric blasting cap wires and connect the other leading wire end to the blasting machine posts. The connection with the electrical blasting machine should be made the last thing before firing, after you are sure that the charges are all ready and after every person and animal is out of the way of the flying pieces.

When the blast is all connected together ready to fire, except attaching the leading wire to the machine, give the handle of the machine one or two light strokes, to make sure that it is working smoothly and to charge the magnets. Then attach the leading wires to the binding posts on the machine, making sure that both the binding posts and the wires are bright and clean where they come together. Raise the handle of the machine to its full height and push it down with speed. When the handle starts on its downward stroke, the pinion immediately clutches the armature and starts the generation of current. The current, growing stronger as the stroke proceeds, causes considerable resistance toward the end of the stroke. The current generated is directly in proportion to the speed with which the handle is pushed down, especially just before reaching the bottom. Any let up toward the bottom will cause a drop in the current and may result in misfires. Therefore, make it an invariable rule, whether the shot be large or small, to bang the handle down hard and carry the stroke with all possible speed to the bottom. Try to knock the bottom out of the box. Machines which operate by the twisting of a handle must be handled equally quick.

When more than one charge is to be fired the different charges must be connected together. The diagrams will help you to understand how this should be done. For nearly all agricultural blasting the connection in one series is the best—that is, connecting each charge to the next one and so on until they are all joined, with one loose electric blasting cap wire from the two end charges of the series. (See diagram A and D, page 163.)

Once in a while, where the series is long and the charges are in a line, you can arrange to have the 2 loose wires at the same end of the series by making the connection, not to each next charge in the row, but to the one beyond and at the farther end doubling back and connecting the missed charges. Do not use this method where it involves many splices with connecting wire.

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In a bulletin of this size it is impossible to give a comprehensive statement of electric firing. But to give some idea, it can be stated that an electric blasting cap requires 1 to 1½ amperes to insure firing. This amount of current will fire one cap or many in a series. To force this amount of current through the wires requires a certain voltage, the amount depending on the size and length of all the wires, and on the joints. One bad or poorly wrapped joint will increase the resistance of the circuit more than several caps. The voltage of the current required to fire any circuit usually can be computed by an expert when the details of the wiring system are explained to him.

**A**

*Straight series connection for use with blasting machine*

**D**

*Examples of zig-zag series connections*

Ways of connecting up charges for electric firing.
Electric blasting machines are constructed to give a sufficient amperage and voltage for firing properly the number of caps specified as the capacity of the machine when connected in a series. If too many caps, or more than usual wiring is connected to any machine, misfires will result. Other current can be used in place of that supplied by a machine, provided it has enough and not too much amperage and voltage. Too great a current will burn out wires without firing all the charges. Too little current sometimes may fire a part of the charges or none.

Bare connections at the charges or back along the leading wire should be raised off the ground by stones, sticks or piles of dirt placed under insulated parts of the wires at each side of the splice. During a thunder storm, do not stand near any of the charges that have been connected. Avoid dragging the leading wire over bare or rough ground as much as possible, and particularly avoid kinking it. Be careful not to break or tear or scratch the insulation of any wires.

Do not attempt to fire through a long length of leading wire wound in a coil or on a reel. The induction, leakage or short circuit of current in the coil of wire causes the blasting machine to deliver a slow discharge, which is fatal to proper firing. Leading wire that is water-soaked or that is covered with mud will lose a considerable part of its current.

Misfires

Many of the accidents noted each year in blasting operations are the result of attempting to examine misfires too soon. If misfires occur with fuse firing, stay away from the shot at least 2 hours. It is better to wait until the next day, for the spark may linger 24 hours and still cause an explosion. (See page 151.) Rock and stump misfires are to be avoided especially. When you are firing the charges electrically, you may approach the shot in fifteen minutes after an attempt has been made to fire the shot.

Misfires are due to the following named causes. The remedies for them are care in preparing the charges and in loading, the details of which are given in the proper chapters.

With cap and fuse firing, misfires are caused by having the end of fuse pulled back a little from the bottom of the cap, by crimping the fuse too tightly with a groove crimp and shutting off the spark, by damp or wet fuse, especially at the end of the cap, by defective cap, by the cap getting pulled out of the explosive, by kinked, damaged, broken or pinched fuse, by failure to light fuse. A great many misfires were never fired at all. With electric firing the reasons for misfires may be damaged wires in the hole, causing short circuits, defective caps, overloaded blasting machine (trying to fire a greater number of electric blasting caps than the machine is designed for), cap pulled out of explosive, bad wire connection at some point, or broken wire.

If you find after due time that for some reason the charge cannot be fired by lighting the old fuse or by sending current through the wires, you must deal with a real misfire.

The best thing to do is to put in another, lighter charge in a new hole made 6 to 12 inches from the original one. The explosion of the new charge will explode
the old one. Never touch the tamping in the old hole unless you know just how deep it is, or how many inches of it there are above the charge. Once in a while the tamping may be dug out of a blockhole misfire. It seldom pays to do this in stump blasting, and never in ditching, or soil blasting. At best it is a dangerous operation. Mudcap charges can be opened and new primers inserted without danger or difficulty. This should be done by removing part of the mud at another point, and inserting a new cap and fuse, or electric blasting cap, as the case may be.

**Cap (Detonators)**

Blasting caps are little copper tubes closed at one end, 1\(\frac{1}{2}\) to 2 inches long and something less than a quarter of an inch in diameter. At the bottom is placed several grains of a high explosive that is very powerful and exceedingly sensitive to heat, shock and friction. This high explosive usually is fulminate of mercury, but often is other material. They are packed in small tin boxes, open end up, usually 100 to the box.

The purpose of the blasting cap is to supply the shock and heat necessary to detonate the charge of dynamite to be fired. So sensitive is the detonating material that it would be impossible to handle the little bit of explosive in the caps if it were not protected by the copper shell. Even at that caps must be kept free from jars and from heat and sparks to avoid premature explosion.

The strength of caps is carefully regulated by the makers to fire the dynamosites and powders on the market. The explosive material with which the caps are loaded is such as will deliver a shock and a degree of heat of the strength and violence required. The caps are numbered according to strength. All dynamosites and powders used for agricultural blasting require at least a No. 6 cap. If they are chilled a little, but not frozen, they require No. 8. It is the part of wisdom to use No. 8 caps all the time, especially for propagated ditch blasting, if you can get them. They give you a margin of strength should moisture or other causes weaken them in storage.

Blasting caps must be used with fuse. And before they are inserted in the cartridge of explosive they must be fixed to the fuse properly. (See pages 144 to 147.) It is the spark which travels down the fuse that fires the cap.

Electric blasting caps are made on the same principle as ordinary blasting caps. They have the copper tube, the explosive at the bottom, etc., but they differ in the way this explosive is fired. Instead of by a powder spark they are fired by a red-hot wire that is heated by an electric current.
Every electric blasting cap has fitted in it 2 small copper wires, which must be considered part of the cap. Down near the bottom of the cap is a delicate bridge of finer wire. The entire arrangement is held in adjustment and sealed by a casting of sulphur-like substance.

For fuse blasting you must use regular blasting caps, and for electric blasting you must use electric blasting caps. It is impossible to substitute one for the other. Never pull at the wires in an electric cap. It is dangerous and may loosen or throw out of adjustment the arrangement of wires inside. And never try to dig out the wires of an electric cap or to dig or to punch the explosive in the bottom of a blasting cap.

**Fuse (Safety Fuse)**

Fuse is used for firing black blasting powder and for firing dynamite and high explosive powders through the medium of a cap. It is made by enclosing within a covering a train of special black powder and an inflammable cotton string. The spark runs down this powder train.

The powder used in fuse is specially made for the purpose, is pulverized and is highly compressed by the covering of the fuse. The covering itself is made of varying materials, depending on the conditions under which the fuse is to be used. For dry work it is only enough to hold the powder in place and to keep the powder train from getting broken. For damp and wet work it is made waterproof by increasing the number of layers in the covering and by adding varnish, coal tar, as other waterproofing material.

There are many brands of fuse on the market. In buying fuse you must bear in mind the character of your work. For work that is entirely dry you can use ordinary cotton or hemp fuse with satisfaction, if it is large enough to fit a blasting cap snugly.

For work in damp ground, use a fuse in which the cotton or hemp is covered with one layer of waterproof tape or other material. This is called single-tape grade or may be known by brand name only. For work where the ground is wet, such as in stump and stone blasting in damp or wet weather, use a double-covered fuse—fuse that has two layers of tape or other material over the cotton.
covering and waterproofing material added. For work where water covers the charges it is best to use fuse with three layers of tape or other material and full waterproofing. This is called triple-tape fuse or may have special brand names. When buying fuse for general farm work, it is well to get a water-proof grade, since it can be used for both wet and dry work.

Most reliable fuse burns about 2 feet per minute when in perfect condition. If it becomes damp, it burns much slower. Cases have been known where the spark smouldered in damp fuse for hours without traveling more than a few inches. Another source of uncertainty is where fuse has been pinched. It may take the spark a minute or an hour or a day to get past the pinched point.

When fuse is cold, it is hard and brittle, and may crack open when unrolled. If it gets too warm, its waterproofing material may penetrate to the powder train inside and ruin it; or the covering may first soften and then harden, in this condition breaking as though cold when unrolled. If grease is allowed on the cover it may combine with the waterproofing and ruin the powder inside.

Handling Explosives

Dynamites in boxes can be hauled freely in spring wagons or auto truck. You should see that no bolt heads or other metal parts project from the wagon boxes to strike the boxes of explosives. Sweep all dirt out of the wagon. Have the beds clean or covered with straw or blankets.

Go over your wagon and harness before you load dynamite to make sure they will not break down while you have the explosive aboard. Be sure you have the hitching straps or tie-ropes along, and do not leave the horses standing without tying them securely. Break no colts while hauling explosives. If you use a motor, stop it and set the brake tight before you leave the load. In driving through a town stay away from dangerous crossings.

Keep the cartridges of explosive in their original boxes until you are ready to use them. Don’t have them around loose. In carrying them to the field, use a wood basket or a box and not a metal bucket. Always protect explosives from all possibility of being reached by falling sparks or from match heads or other source of fire. Rain, hot sun and the like must be kept away from explosives. Use care to lay cartridges or set the boxes or baskets containing explosives where they will not fall down, be blown over by wind or knocked over by careless people or by animals. Cattle will eat cartridges of dynamite because of their sweet and salty taste. The explosive will make them sick, sometimes kill them.

Since nitroglycerin often will cause headache when absorbed through the skin it is best to wear gloves when handling the cartridges. For this same reason some people punch holes for caps in the cartridges with a piece of wood rather than with the handle of the cap crimper.

Caps should not be carried in the same basket or box as explosive, but should be carried separately. Take only enough along to do the work in view and carry them in the tin boxes they come in. Many serious accidents have been caused by blasters having loose caps in their pockets during work or afterwards. Sooner or later a chance jar is likely to set them off. When several caps have been taken out of the little tin box in which they come the rest will be loose and will rattle about. This should be stopped by filling up the empty space with paper.

The handling of caps is not dangerous provided you do it intelligently and with care. Keep them safe from any jars or heat. You can sometimes do
Handling

many foolish things with dynamite without serious results to yourself, but not with caps. Letting a cap fall to the ground or floor likely will cause it to explode. For this reason you should keep the caps and explosives apart, in hauling, storing, and handling, bringing them together only at the last minute before you prepare the charge to be loaded in the hole. One cap can produce an explosion powerful enough to tear your hands off.

Electric blasting caps must be handled with the same care as regular blasting caps. All caps must be protected from dampness during handling. No trouble will be experienced if you use common sense at every turn, but thoughtlessness and carelessness in the handling of explosives will cause disaster. Bear in mind that when an accident happens with an explosive there is no time to save yourself, and no afterthought will prevent serious injury to you. Forethought is the thing with explosives. In an explosive you are handling an enormous strength. The fact that it occupies small bulk now should not interfere with your imagining it as an enormous engine with power enough to crush you easily, but under entire control if you do your part right.

Storing Explosives and Supplies

The storing of dynamites on farms offers no serious problems, though it may call for some shifting of arrangements to meet proper requirements. The explosives must be kept dry. They should be kept cool. This means that any ordinary temperature of the air is all right, except that in hot weather the room where the explosive is kept should not get warmer than 80 or 90 degrees. If it is properly ventilated day and night it will not. Probably the best common storage place for explosive is in an outbuilding under the floor of which the air circulates freely and with a ceiling between the room and the roof. It should be strong, and should be provided with a lock. A responsible person should have charge of the key at all times.

The explosive should not be kept in a garret, because the hot sun beating down on a roof will raise the temperature under the roof away past the 100 degree mark.

Dampness is injurious to explosives, as noted on page 143, and dynamites and powders must be kept where moist air will not surround them. The ideal storage would be fireproof, but since this is out of the question on the average farm, the best that can be done in that respect is to guard against fire. It is well to make sure that the explosive is out of reach of any stray or malicious bullet that might be fired into it.

Look to your insurance policies and see whether they provide against the storage of explosives in any of your buildings. Store the explosive in a building not covered by the insurance.

Where large quantities of explosives are to be stored as a regular thing, or for any length of time, it is advisable to consult the makers of explosives or others experienced in their handling in regard to the location and construction of a magazine. A magazine can be set up cheaply and can be made fireproof, bullet proof, thief proof, well ventilated, dry and safe in every way. It should be built of brick. Any explosive maker will furnish plans without charge. In any case explosives should be stored at least 50 yards away from any other buildings and from roads or railroads.
Blasting caps of any kind must not be stored with dynamite or powder. Caps are even more subject to damage by moisture than explosive and must be stored accordingly. Caps must not be allowed to become heated.

A statement of the ways in which explosive deteriorates will help in selecting a proper storage place for it. In temperatures higher than 80 degrees troubles may begin. Long continued temperatures of 90 to 100 degrees may cause the nitroglycerin to leak out of the absorbing material and to gather inside the wrapping on the lower side of the cartridges, or may even cause it to leak out of the wrappings through the boxes and to the floor.

Strict watch should be kept on the cartridges and the boxes to catch any such condition. If leakage occurs, turn the explosive over and reduce the temperature. Burn the empty boxes one or two at a time out away from buildings, and scrub the floor where the leakage occurred with a strong solution of sal soda. This will decompose the nitroglycerin. If it becomes necessary to destroy a little explosive without detonating it, the job can be done by immersing it until dissolved in such a solution, stirring it gently with a wood paddle.

If the cartridges feel smeary it is possible they are leaking. The test is to lay them on white paper for a little while. If they are leaking they will stain the paper, otherwise not.

At a temperature of 105 degrees nitroglycerin explosives will lose 10% of their strength in a few days by evaporation. Repeated freezing and thawing is bad for explosives, especially if the thawing is rapid. Slow thawing will not damage them. After explosive once is frozen and thawed, it will freeze much easier again.

When stored for many months explosives are liable to decomposition of some of their elements, especially if they get damp or too warm. One of the marks of this is greenish stains inside the cartridge wrappings. No length of time can be stated for the keeping of explosives, because it practically all depends on conditions. Under favorable conditions most dynamites and powders will remain in good shape for years. Again, a month of improper storage will ruin them and make them dangerous to handle. They develop troubles sooner in the light than in the dark.

Deteriorated explosives are likely to be dangerous—far more so than normal explosive. Keep watch over what you have in stock. Maintain proper conditions as far as possible, but if they show troubles do not hesitate to condemn them.

**Shipping Explosives**

The shipping of high explosives is controlled by the Interstate Commerce Commission, and the rules and regulations are very strict and rigid. Most of them are embodied in an Act of Congress of March 4, 1909, and violations are punishable with fines of not more than $2,000, or imprisonment for not more than eighteen months, or both. The person making the shipment is responsible.

A copy of the rules and regulations can be secured from the Bureau of Explosives, 30 Vesey Street, New York City, or can be read at any freight station where there is an agent.

The rules provide that no explosives (other than certain exceptions named) shall be carried on any train, boat, trolley, or other vehicle carrying passengers
for hire, and that no explosives under deceptive or false markings or understand- ing shall be delivered to a common carrier; and further, that all other regulations shall be complied with.

In shipping by railroad no caps or detonators of any kind can be sent in the same car with explosives. In practice the railroads usually send them by another train, which works out to be another day in the cases of nearly all shipments. This is responsible for some delay in delivery of explosive shipments. Do not expect to have explosives come through as quickly as you would other freight.

Explosives cannot be shipped by express or by mail, but are sent by freight. The railroad company is required to place the packages in a certain way inside the car and to brace them with lumber. In case of car-lot shipments the shipper must furnish this lumber and do the bracing.

The regulations provide that railroads must have 24 hours' notice of shipment of explosives, and that shipments must be removed from the receiving station within 24 hours of their arrival there. The packages must be plainly stenciled with the name of shipper and consignee, and bills of lading must conform with certain specifications.

Empty boxes which once have contained explosives must never again be used for shipments of any kind. Farmers who have attempted to ship vegetables or other farm products in such boxes have unwittingly gotten themselves into trouble on account of this regulation more than once.

Danger and Safety

Modern explosives have been developed to the point where they need not be feared by anyone who handles them intelligently. Speaking in a comparative way, they may be used with no greater dangers than there is in the using of horses, mowers, traction engines, sawmills, or other farm equipment, or than there is in using shotguns or rifles.

The general use of explosives on farms is so new that many people distrust them more because of their newness than from a clear understanding of any actual dangers their use may hold. A review of what the dangers are may help users of explosives to avoid them, and may help to build up the reader's belief in the safety of explosives.

There is some danger in the handling and transporting of explosives, but it depends very largely on the exposure of the dynamite or powder to heat, flame, sparks, blows and friction. The directions say to keep explosives dry, to keep them at a temperature less than 90 or 100 degrees F., to keep them safe from sparks, and to avoid blows and shocks. If these directions are followed there will be few accidents.

Probably the most common cause of accidents with explosives lies in violation of some of these primary rules while thawing frozen cartridges of dynamite. Freezing makes the high explosive less sensitive to the simple direct shock of a blasting cap, unaccompanied, as it is, by any friction. But at the same time freezing makes the explosive more sensitive to friction in any form.

For this reason, though a frozen cartridge of dynamite cannot be fired properly by a blasting cap, it is very likely to be fired prematurely by a chance light blow from any object touching it, by your slitting the wrapping paper with a knife, by breaking the cartridge in two, or by attempting to punch a hole into it to insert a cap. (These operations are entirely safe when the explosive is normal.) If the cartridge is dipped in warm water or exposed to steam, or is laid on anything which is warmer than about 125 degrees, free nitroglycerin likely will leak out.
and fall in drops. And one drop of nitroglycerin falling only a few inches may be exploded itself and may explode all dynamite that is near it.

Throughout the entire course of handling the explosive, from the freight station to the hole in the stone or the ground, you should remember the five cautions which will be repeated: Keep it dry, keep it cool, keep it away from sparks and flame, and keep it safe from blows and friction. Be careful—as careful as you would in driving a big automobile or a traction engine. Then you will be secure from any accidents, and explosives will be safe to handle.