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SCHOOL OF MINES QUARTERLY.

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SPRING-POLE DRILLING.

BY EDGAR G. TUTTLE, '81.

THE spring-pole drilling outfit here described, is one that can be used with advantage in making explorations where drilling to a depth of about 200 or 250 feet or less is required.

It is suitable for determining, within these limits, the depth and thickness of coal-beds, stratified rocks, ore-deposits, etc. It can also be used in drilling for water.

Spring-pole drilling has, to a great extent, been displaced by horse-power, steam and diamond drilling machines: but where a few holes are to be drilled, or at shallow depths, and speed is not of importance, spring-pole drilling has manifest advantages over other methods, on account of its moderate first cost, the readiness with which it can be moved from one location to another, its few requirements, and, consequently, small cost of operation and maintenance.

Especially is this method of advantage in countries where water is scarce and feed for horse-power or fuel for steam or diamond drilling are not readily obtainable.

For explorations at greater depths than 200 or 250 feet a horse-power, steam or diamond drill is necessary.

A horse-power drill is suitable for moderate speed and depths, a steam drill for greater speed and depth, and if the explorations are very extensive and deep, and speed is an object, the expense of a diamond drill will be warranted.

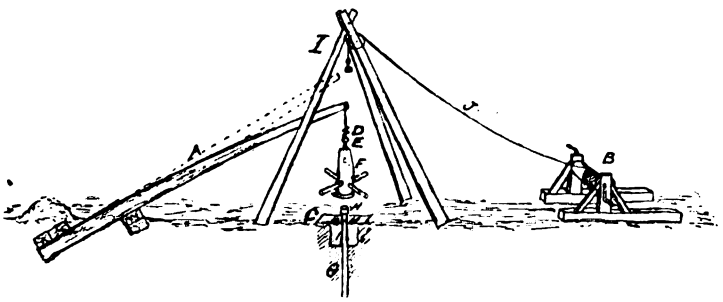
If a core-drilling is necessary, the use of a diamond drill is at once determined.

In these cases special arrangements may be necessary for obtaining the necessary feed for a horse-power drill, and fuel and water for a steam or diamond drill, especially in dry or barren countries. If these are to be hauled, teams and wagons will be required for hauling the machinery from one location to another and hauling fuel and water.

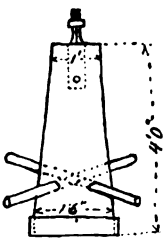
About one-half to one ton of coal, or its equivalent in other fuel, and 1000 to 2000 gallons of water may be needed daily with the latter outfits, and these items may considerably increase the cost of drilling by steam, etc., as compared with the spring pole.

The accompanying illustrations show the detailed construction of the special tools for spring-pole drilling. They can be made in

FIG. 1.



Hitch Knot (D).



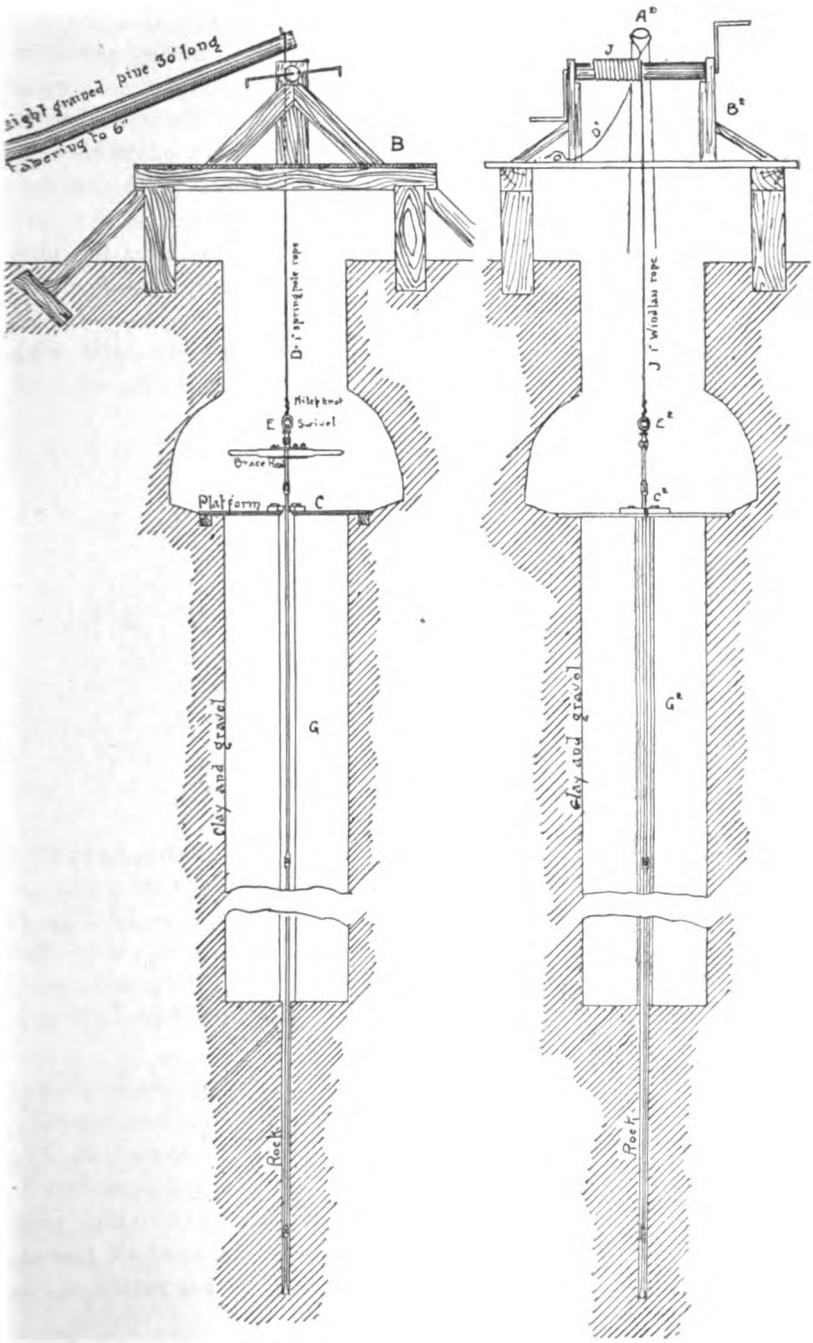
Pipe Driver (F).

Splicing Iron (K).

any blacksmith shop, and repairs, sharpening, etc., can be kept up in the field with a portable forge, if this is accessible.

Fig. 1 shows the spring-pole outfit erected entirely above ground

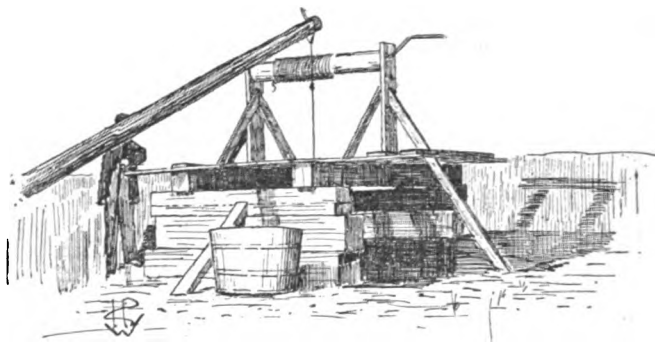
FIG. 2.



and fitted up for pipe driving and earth boring and, subsequently, drilling.

This arrangement is adopted, 1st, where earth boring and driving of pipe for casing to the rock are necessary either on account of the soil being wet or caving, or on account of the soil being of considerable depth, or where it can be bored and cased cheaper than it can be excavated by shafting. 2d. Or the same arrangement is used where the rock strata begin at the surface and rock drilling from the start is necessary. In this case the pipe driver and piping are replaced by the rock-drilling arrangements as shown in Fig. 2.

Fig. 2 shows the arrangement of the spring-pole outfit, with working platform below the surface, and in a special case where it



View of Spring-Pole Outfit Erected as Shown in Fig. 2.

was cheaper to sink a shaft 4 feet square through dry, tenacious soil 45 feet deep to the rock, than to bore and drive casing pipe.

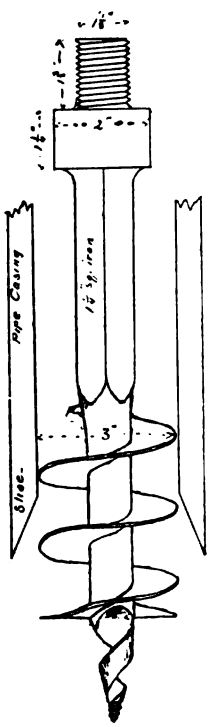
The arrangement of the platform below ground, as in Fig. 2, has the advantage over the arrangement shown in Fig. 1 in that the outfit is more compact and accessible. The spring pole need not be erected with its end as high above the ground and the derrick is not needed.

Even if earth boring and driving of pipe casing are necessary for considerable depth, where a pit 12 feet deep can be excavated and a platform erected 8 feet below the surface, as shown in Fig. 2, such an arrangement is best. The earth-boring and pipe-driving tools can then be used from this point downwards to the rock. The pipe driver shown in Fig, 1 can likewise be used in the arrangement shown in Fig. 2, by attaching it to the swivel of the

spring-pole rope in the place of the drill rods, which are shown in position, ready for operating, in Fig. 2.

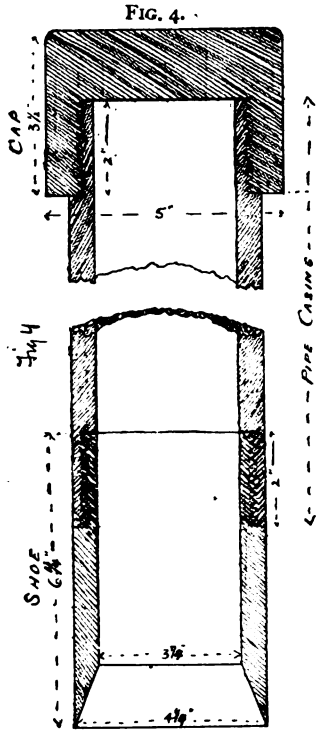
Where gravel or boulders are present in the soil above the rock, it may be necessary to sink a shaft to the rock, as shown in Fig. 2, and erect either a wooden or pipe casing to the working platform, to prevent dirt and water, with drillings, from falling into the drill hole.

FIG. 3.



Earth Auger.

FIG. 4.

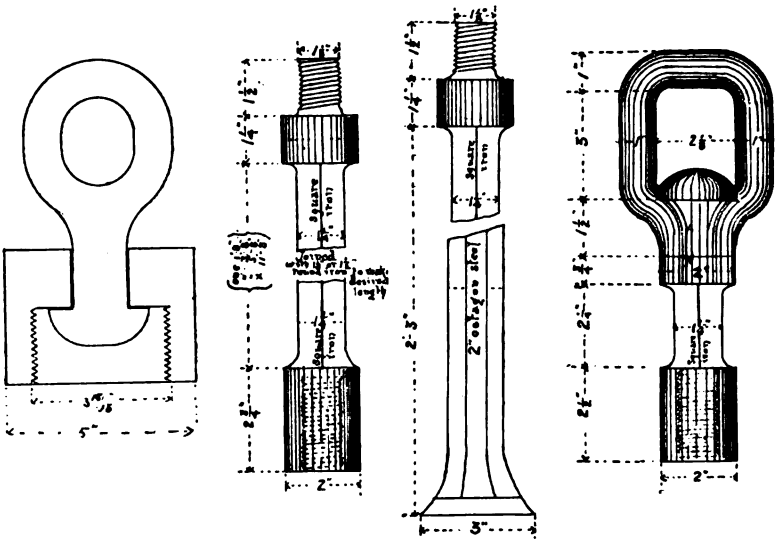


Pipe Casing, Cap and Shoe.

Figs. 3, 4 and 5 show the special earth-boring and pipe-driving tools used in connection with the arrangement shown in Fig. 1 and the drill rods shown in Fig. 6, which are also used for attaching to the earth-auger in boring.

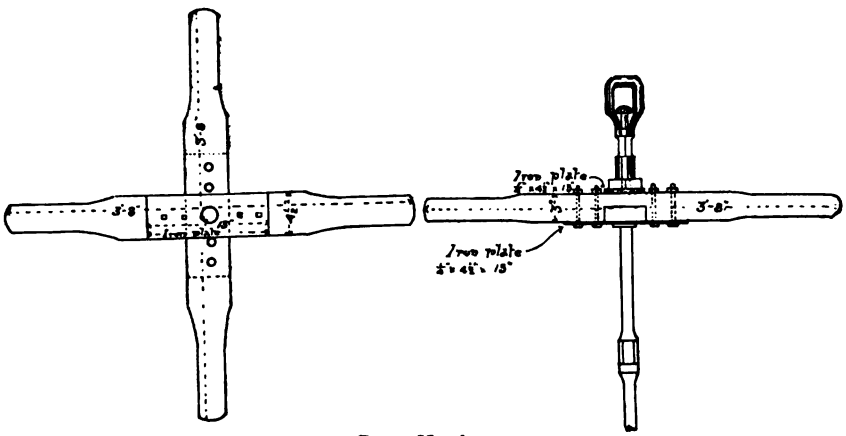
Fig. 4 shows a section of the pipe fitted up with a shoe and a cap ready for driving. The shoe is bevelled and pointed, so as to facilitate its wedging into the soil from the blows delivered on the cap by the pipe driver. The pipe lift, Fig. 5, is used for removing

FIG. 5. FIG. 6. FIG. 7. FIG. 8.



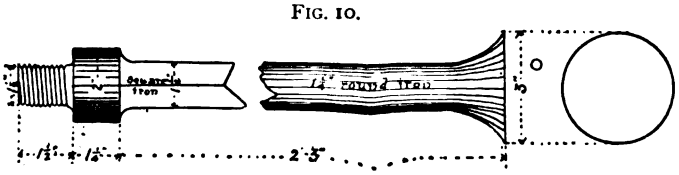
Pipe Lift. Drill Rod. Drill Bit. Swivel.

FIG. 9.



Brace Head.

FIG. 10.



Reamer.

the pipe from a hole. It is screwed on to the end of the pipe, being interchangeable with the cap, and by means of the rope and windlass it is lifted, assisted with screw jacks if the pipe is tight in the soil or of considerable depth.

Figs. 6 to 16 inclusive show the special rock-drilling tools. The drills, rods, swivels, reamer, fishing tools, heavy sand pump, pipe driver (Fig. 4) and the earth augur (Fig. 3) are fitted with connecting screw ends, as shown, which are 1⅛ inches diameter to outside of threads and 8 threads to the inch.

The accompanying list of tools gives the complete outfit needed:

List of Tools and Equipment.

Reference.

Figs. 1, 2, A. 1 round pine spring pole, 30 feet long, 6 inches and 10 inches diameter.
" " B. 1 windlass, with supports.
Fig. 1, I. 1 derrick, with pulley.
Figs. 1, 2, C. 1 platform for foot wrench.
" " D. 50 feet of 1-inch Manilla rope for support of rods or pipe driver to spring pole.
" " J. 50 feet of 1-inch Manilla rope for lifting rods or pipe with windlass.
250 feet of ½-inch Manilla rope for sand pump.
" " K. 1 splicing iron 10 inches long.

Boring and Pipe-Driving Tools.

Fig. 1, F. 1 pipe driver, oak, 4 feet long, 12 inches and 18 inches diameter, iron bound.
Fig. 3, 1 3-inch earth auger, with same rods and brace head as used for drilling in Figs. 6 and 9.
Fig. 4, 1 driving cap.
1 driving pipe 1 foot 2 inches long.
1 " " 2 feet 2 " "
1 " " 3 " 2 " "
1 " " 4 " 2 " "
1 " " 5 " 2 " "
33 " pipes 6 " 2 " " for 200 feet of casing.
1 shoe 6¼ inches long.
Fig. 5, 1 pipe lift.
1 chain wrench for pipe and cap 4¼ and 5 inches outside diameter.
1 alligator " " " " " "
Fig. 18, 2 screw jacks for loosening casing.
2 clamps for holding and raising pipe with jacks.

Rock-Drilling Tools.

Fig. 6, 1 rod 1 foot 8 inches between shoulders, 1 " 3 feet 8 " " " 1 " 5 " 8 " " " } Made of 1¼-inch or 1½-inch round iron, with ends near joints of 1¼ inches square iron for holding with wrench.
16 rods 11 feet 8 inches between shoulders, for 200 foot hole.

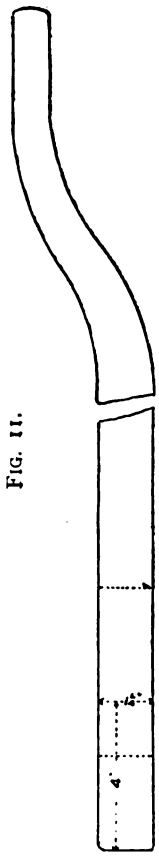


FIG. 11.

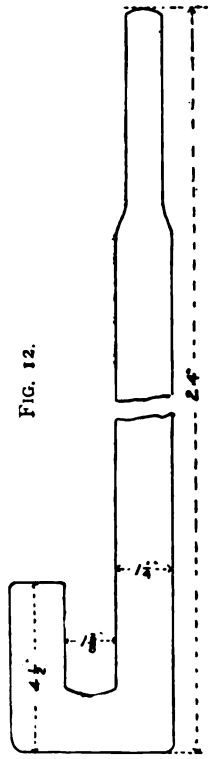


FIG. 12.

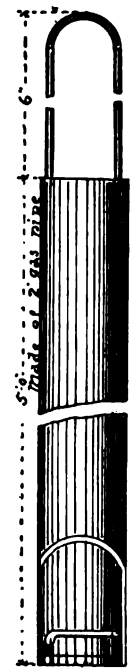


FIG. 13.

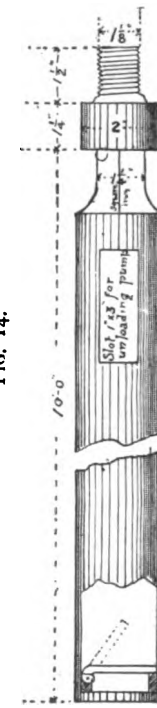


FIG. 14.

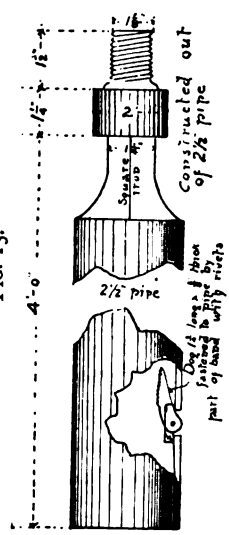


FIG. 15.

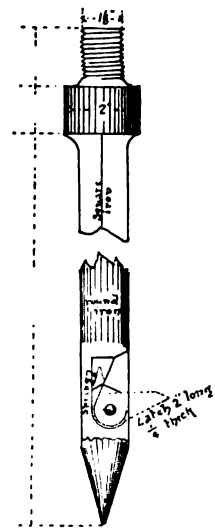


FIG. 16.

Fig. 11.—Foot Wrench.
Fig. 12.—Hand Wrench.
Fig. 13.—Sand Pump for Light Drillings.
Fig. 14.—Sand Pump for Heavy Drillings.
Fig. 15.—Grab for Drills and Rods.
Fig. 16.—Grab for Sand Pump.

Fig. 7,	6 drills, with 3-inch steel bit, made of 2-inch octagon steel.
Fig. 8,	2 swivels, one attached to windlass rope and one to spring-pole rope.
Fig. 9,	1 brace head for operating drill and rods.
Fig. 10,	1 reamer for truing hole.
Fig. 11,	1 foot wrench for holding rods on platform.
Fig. 12,	1 hand or disconnecting wrench.
Fig. 13,	1 sand pump for light drillings.
Fig. 14,	1 " " coarse or pasty drillings.
Fig. 15,	1 fishing tool—Grab for drills and rods.
Fig. 16,	1 " " sand pump.
	2 barrels or kegs for holding water.
	black oil for rod and pipe joints.

In addition to above are needed one small kit of blacksmith's tools, anvil and forge for sharpening and repairing. A few machinist's tools for pipe-fitting and threading, and carpenter tools for erecting windlass and platforms.

Erecting the Spring Pole, Platform, Etc.

The spring pole is erected as shown in Figs. 1 and 2 with its upper end nearly over the location for the hole, or that part from where the rope suspends about 2 or 3 inches back of the line of the hole, so that when the weight of the rods comes on the spring-pole in drilling, this point will come over the hole or travel ½ inch to 1 inch from one side to the other of the hole when being operated.

There should be sufficient height between the upper end of the spring pole and the working platform to operate the pipe driver in sinking pipe or the brace head in drilling.

The pulley of the derrick in Fig. 1 or the windlass reel in Fig. 2 is erected 13 feet or more above the working platform so as to have enough height for handling the longest pipes and rods in raising and lowering them.

If the platform is arranged as shown in Fig. 2 a distance of 8 feet below the surface is sufficient.

In order to handle the pipe in driving, it is necessary to have access to it for 3 or 4 feet below the platform level, so that if the outfit is all erected above ground as in Fig. 1, it will be necessary to sink a pit centrally on the location of the hole and 3 or 4 feet deep below the working platform (C) or else erect the working platform 3 or 4 feet above the level of the ground and raise the end of the spring pole and windlass reel or pulley a like amount. The

platform has a central removable blocking with a hole large enough to introduce the piping and rods.

The method of operating the spring pole is as follows:

Driving Through Soil or Loose Material.

The pipe driver is placed in position as shown in Fig. 1 for operating above ground. The screw end of the upper part of the pipe driver being screwed into the end of the swivel attached to the spring pole rope. If the pipe driver is to be operated below ground, as in Fig. 2, the connection with the spring-pole rope would be the same, the brace head shown in Fig. 2 being removed and replaced by the pipe driver.

A six foot length of pipe is fitted with a cap and shoe as shown in Fig. 4 and placed in position for driving. The lower end is sunk some distance in the ground by hand. The upper end is guided by the platform blocks, while the lower end is sunk into the soil by the blows of the pipe driver delivered upon the upper end. In driving not more than three feet of the pipe extends above the platform, more than this necessitates the pipe driver being too high for ease in operation. About 1½ to 2½ feet above the platform is better.

The pipe driver is adjusted by the rope of the spring pole being raised or lowered as needed and held in place by a hitch knot in the rope at the swivel end.

In starting to drive the pipe, the pipe driver is fastened by a hitch knot so that its lower end will nearly rest on the cap of the pipe.

Two or four men standing between the handles of the pipe driver, and each with a hand on a different handle, then raise and lower the pipe driver by means of the handles and assisted by the spring of the pole, they let it strike the cap of the pipe squarely on its down blow. After the pipe has been driven 4 or 6 inches, the men at the handles instead of exerting more force on the up stroke find that it is necessary to apply more strength on the down stroke and less on the up stroke as the spring pole assists in lifting the pipe driver. After driving 6 or 8 inches the hitch knot is then loosened by a splicing iron and the driver lowered within an inch or so of the cap, the knot tightened and the driving repeated as in the beginning of the operation, until the pipe has been driven down about 2 feet, or so that about 6 inches remain above the plat-

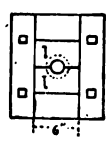
form. Then the cap is removed and a 1-foot length of pipe added with the cap screwed on top. This is similarly driven down until 4 or 6 inches of the pipe remain above the platform, or enough so that the pipe and cap can be grasped by wrenches to permit of uncoupling.

The cap and the 1-foot length of pipe are now removed and a 2-foot length added with the cap screwed on top. This is again driven down until about 6 inches of the pipe remain above the platform when the cap and 2-foot length of pipe is removed and similarly, a 3-, 4-, 5- and 6-foot length are in turn put in place, the 6 foot length remaining connected with the first 6-foot length and shoe and driven in the ground to form the second length of the casing. The driving with the 1-, 2-, 3-, 4-, 5- and 6-foot lengths of pipe is then repeated, the 6-foot length remaining in place each time and being driven in the soil to form a part of the casing. The operation continues until rock is reached.

If the soil yields readily so that the pipe drives easily, the 2-, 4-, and 6-foot lengths need only be used, which makes the pipe stand higher above the platform in driving, but reduces the time of changing lengths and cap and increases the speed of driving.

To facilitate the joining of the lengths of pipe in these frequent changes, the opening in the platform C is arranged so as to be readily opened and closed by the loose blocking as shown at *l* in Fig. 17. The joining of the successive rods is required to be done below the platform.

FIG. 17.



Platform set.

The joints of the pipes are oiled to permit of their being easily disconnected. If the soil has not sufficient resistance to hold the lower pipes in place while disconnecting the upper pipe with a wrench, then it will be necessary to make a small platform around the pipe, 4 feet below the platform C (Figs. 1 and 2) on which to grasp the lower pipe with a chain or alligator wrench while disconnecting the upper pipe.

The play of the spring pole varies from 6 to 14 inches, depend-

ing greatly upon its stiffness and the weight of the pipe driver. The weight of the pipe driver will vary from 200 to 600 pounds, depending upon the depth of piping to be driven. The best arrangement is to have a pipe driver weighing 200 or 300 pounds, whose weight can be increased as desired by adding bands or ribs of bar iron.

Boring Through Soil or Loose Material.

After driving the pipe until it ceases to sink in the soil or nearly so, which distance may vary from a few inches to several feet, the pipe driver is removed and the cap and such length of pipe is removed as is necessary to reduce it to about the level of the platform. The earth auger (Fig. 3), is then connected with the desired length of drill rods (Fig. 6) and lowered inside the piping by means of the windlass rope and swivel (see J in Figs. 1 and 2). When the auger rests on the soil in the pipe, the rods should be of such length, that, when the brace-head (Fig. 9) is connected to the top of the rods, it will not stand over 3 or 3½ feet above the platform, so as to facilitate the boring.

Men now turn the brace-head around by pushing on the handles as they walk around the hole, thus imparting a boring movement to the rods and auger. The auger is thus sunk as far as the strength of the men and rods and resistance to the auger will permit. The brace-head is then removed and the rods and auger, with its load of earth, are lifted by the windlass. The operation of lowering and raising the rods, connecting and disconnecting, is described further on under "Drilling."

The auger and rods are again returned into the hole through the piping, and the operation of boring and removing soil is repeated as often as is necessary to penetrate the soil as far as the piping has been driven and such distance ahead of the piping as the nature of the soil will permit. Fig. 3 shows the auger penetrating some distance in advance of the piping.

Even if the soil is slightly caving, it assists the driving of the pipe to remove some of the soil in advance of it with the auger.

Depending upon the nature of the soil, the auger is sunk a few inches to several feet between the operations of driving the pipe. Generally 1 to 3 feet can be driven in ordinary sandy and clayey soils. In some firmer and more tenacious soils a greater distance can be driven. In loose, sandy soil and gravel it will only be possible to sink a few inches at a time ahead of the pipe.

The operations of driving and boring are repeated until the piping is sunk to rock. Then the hole is cleaned and the pipe, driver and cap are removed. Such lengths of casing-pipe are removed or added as will bring the top of the pipe just below the platform, not more than a foot, so as not to interfere with the following operation of handling the rods and wrenches in drilling.

Lowering the Drill Rods.

If a shaft is excavated through the soil to the rock a wooden box can be constructed for a casing from the rock to the platform, as shown in Fig. 2, instead of using the piping for the rods to work in.

In either case, or assuming that the hole has been drilled some depth from the surface or from the bottom of the casing, the operation of lowering the rods is as follows:

A drill-bit, Fig. 7, is fastened to a drill-rod, Fig. 6, then tightened with the wrenches, Figs. 11 and 12, and lowered in the hole in the centre of the platform, C, and through the casing or into the drill hole. The longer rods are used firstly, such as the depth will permit.

The top of the drill-rod is held at the squared part of its shoulder by the foot-wrench, Fig. 11, on the platform, while another rod is coupled to it and tightened by means of the hand-wrench, Fig. 12. The swivel of the windlass rope is screwed to the top of the rod and the whole length of rods is lifted by the windlass a few inches. The weight thus being relieved from the foot-wrench, it is removed and the rods are lowered until the upper end is near the platform. The foot-wrench is again similarly placed around the squared end of the rod and the whole weight of rods allowed to hang from it as it rests on the platform. The swivel of windlass rope is removed and lifted, and other rods are likewise jointed and lowered by the windlass.

On nearing the bottom of the casing or hole, such lengths of the 6-, 4- and 2-foot rods are used as will leave about 2 or 3 feet above the platform when the bit is resting on the rock. The windlass rope and swivel are then removed, and the brace-head, with its swivel, is screwed upon the drill-rod. The entire length of rods is slightly raised and the end of the spring-pole rope is passed through the swivel and tied by a hitch knot. The rods are then

allowed to suspend from the spring-pole and are in readiness for the operation of drilling.

Each joint of the rods is oiled as connection is made, so as to permit of readily uncoupling them when they are lifted.

Drilling.

If the rock-drilling begins at the surface, a hole is first drilled as deep as possible by hand. A drill-bit, Fig. 7, with required length of drill-rods, Fig. 6, are then lowered through the hole in the centre of the platform, C, into the drill-hole. The lower end of the brace-head, Fig. 9, is then connected to the top of the drill-rods and the swivel of the spring-pole rope is secured to the top of the brace-head.

By means of a hook on the windlass-rope or by the two or four men, the brace-head and the length of rods are lifted 2 or 12 inches, depending upon the weight of the rods, and then the lower end of the spring-pole rope is passed through the swivel of the brace-head, tightened and tied in a hitch knot. The weight of the rods is thus allowed to suspend from the spring-pole rope, with the drill-bit an inch or so above the rock, so that by the up and down strokes given by the two or four men at the handles of the brace-head, the bit will come with sufficient force against the rock to deliver a cutting blow on the rock.

Four men operate the drill on heavy work, two men on light work. They stand between the handles of the brace-head, each one taking hold of two handles so that their hands lap. Then, assisted by the springing action of the pole in the return movement, they bear down and release or drop and lift the rods, by the handles of the brace-head, as the case may require at the beginning or end of the drilling to impart the blow with the drill, at the same time they walk around the rods to the left to prevent the rods becoming uncoupled, taking a step with each blow or two so as to turn the rods and drill in the hole while cutting.

The play of the spring pole varies from 4 to 8 inches at the beginning of drilling to from 12 to 14 inches at a depth of 200 feet. After drilling 4 or 8 inches, as above, depending upon the depth of the hole, the hitch knot is loosened by a splicing-iron and the drill, rods and brace-head are lowered so that the drill-bit comes within an inch or more of the rock, depending upon the weight of the rods. This process is repeated until the hole becomes so filled

with drillings as to impede progress. Not more than one or two feet can be drilled at a time when it is necessary to draw out the rods and remove the drillings with the sand-pump, as described further on.

After the drill and its rods have been sunk so that the brace-head comes too near the platform to permit of the men readily operating it, then the spring-pole rope, and brace-head are removed and the rods lifted and the first joint is held on the platform by the foot-wrench, while the rods are changed or other lengths added. Such lengths as may be desired by increments of 2 feet can be obtained by combinations of the 2-, 4- and 6-foot lengths and finally adding a 12-foot rod and repeating again the additions of the 2-, 4-, 6- and 12-foot rods as the hole becomes deeper. The 12-foot rod remains in place to form the increasing length of the drill-rods. The lowering of the rods with the increasing depth of the hole is described under "Lowering of the Drill-Rods."

At the beginning of the drilling, when the weight of the drill-rods is not so great, the adjustment of the spring-pole rope is such that as the rods suspend therefrom they will be a few inches above the rock. This depends also upon the spring of the pole. The blows are then effected mostly by bearing down on the handles; the return by lifting the rods, assisted by the spring of the pole.

As the hole becomes deeper and the weight of the rods heavier the blows are delivered by the downward weight of the rods in addition to the bearing down on the handles. The return being effected by the spring of the pole.

All drilling being necessarily done in the presence of water, if such is not present in the stratas of the rock, the small quantity needed must be arranged for. There must be sufficient to always keep several feet of water in the bottom of the hole for the most rapid progress and the greatest depth of drilling between the removals of the rods.

The reamer, Fig. 10, is used to true the hole if any ridges or projections have been left in drilling, or to enlarge it if the drill-bits become worn so that the hole is less than the regular size. The reamer is worked in the same way that the drill is operated. The fishing tools, Figs. 15 and 16, are for removing drill-rods or the sand-pump, if they drop or become detached in the hole.

Removing the Drill-Rods.

In order to remove the drillings by the sand-pump the rods must be withdrawn as follows:

The spring-pole rope, swivel and brace-head are removed from the drill-rods. The swivel of the windlass-rope is coupled upon the top of the drill-rods and lifted until the first joint comes above the platform. The foot-wrench is then applied to the squared portion of the rod below the joint and the windlass-rope is released so that the weight of the rods suspend by the foot-wrench as it rests on the platform. The rod above the platform is then detached from the lower rods by the hand-wrench applied to the squared portion of the rod above the joint, while the foot-wrench remains firmly in place on the platform. When the upper rod is removed the swivel of the windlass-rope is lowered and attached to the top of the rod suspended in the jaw by the foot-wrench. The length of rods is then again raised by the windlass and the weight on the foot-wrench is relieved, which is removed and again grasped around the next lower rod as this is raised above the platform by the windlass. The operation is then repeated of letting the weight of rods rest on the foot-wrench and removing the swivel of the windlass-rope, uncoupling with hand-wrench, and so on until the whole length of the rods is removed.

Use of the Sand-Pump.

The sand-pump, Fig. 13, is then lowered into the hole with a half-inch rope into the mixture of drillings and water, and is worked up and down by pulling up and letting go of the rope until the settlings have been well stirred up in the hole. The settlings then enter the pump through the clack-valve at the bottom. As soon as the pump is down as far as it can be lowered and is filled with drillings it is raised by hand or by the windlass and emptied. The hole will be cleaned after drawing up two or three sand-pumps full of drillings or as soon as the water discharges clear from the pump. By sounding with the pump it can be distinguished when the sand-pump has reached the bottom of the hole by the sharp jar in dropping it while holding the rope taut.

If the drillings are very heavy or pasty, it is necessary to use the sand pump, Fig. 14, which is lowered with the drill-rods and

operated similarly as in drilling until filled with sediment, and is then removed.

Heavy drillings occur in drilling through hard or flinty sandstone, spars, iron stone, etc., forming a coarse drilling as compared with that of easier-cutting formations—shales, slates, etc.

Pasty drillings are formed in the presence of clayey slates, tending to slack in the presence of moisture, etc.

Examination of the Drillings.

The drillings should be carefully examined, especially when searching for thin strata or seams. When the drillings from the neighborhood of such horizons are raised they should be poured out in separate places and allowed to dry for examination.

When a change in the hardness of the rock or formation occurs, the penetration of the drill into it can be distinguished by the difference in the sounding, ringing or yielding of the drill, due to the increased difficulty or ease in cutting. In this case, or when approaching the formation being sought for, drilling should stop and the rods be removed and the hole cleaned. The depth of the hole is noted at these various stages. Drilling is resumed, an inch or so being driven at a time, until the nature of the formation entered is determined. If it is one of importance, the drillings raised each time are poured out, dried and kept separately.

In coal-beds, as in other formations, the quality may vary at certain portions of its section. For this reason, each few inches of the drillings therefrom is kept separately for such examination and analysis as may be necessary.

Removing the Casing.

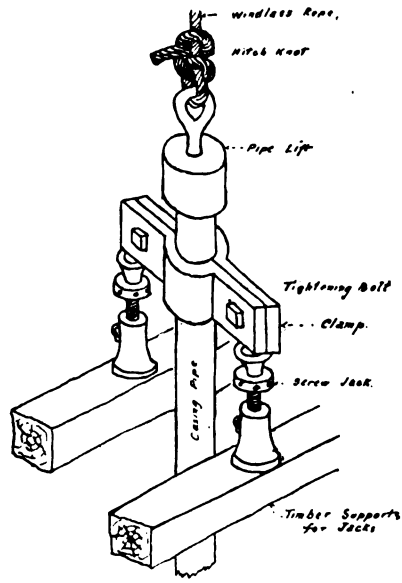
After the hole has been drilled to completion, the pipe casing is withdrawn and the hole abandoned, unless it is to be used for some other purpose.

To remove the casing, the pipe lift, Fig. 5, is screwed to the top of the piping and the windlass rope tied to it. If the casing is very shallow, the pipe can be raised by the windlass if at the same time a long pipe or chain wrench is applied to the casing, turning it in the same direction as in coupling, but with sufficient force to turn the whole length in the ground.

If the casing is of considerable depth, it is necessary to bind two iron clamps securely to the pipe below the shoulder of the

pipe lift. Two screw jacks, resting on solid timbers laid across the platform and bedded in the earth, are then placed under these clamps, one on either side of the pipe. Power is then applied to both at the same time, and as they begin to loosen the pipe from the soil, it is pulled upon by the windlass rope. This arrangement is shown in Fig. 18. The pipe may be thus readily loosened or it may require a continual use of the clamps and jacks, readjusting them with each few inches play of the jacks, to remove all the casing.

FIG. 18.



If the friction of the pipe against the soil, in removing it, is not sufficient to support it while uncoupling, it is supported by means of the clamps, as follows: The pipe is raised 6 or 12 feet, as most convenient for uncoupling. The clamps are then secured around the pipe just below the joint, and allowed to rest upon the timber supports, while the lengths above are uncoupled with a pipe wrench and removed. The pipe lift is then coupled to the pipe above the clamps; the latter are removed, and the pipes again lifted further up the hole by the windlass, the clamps again applied, and so on until the casing is removed.

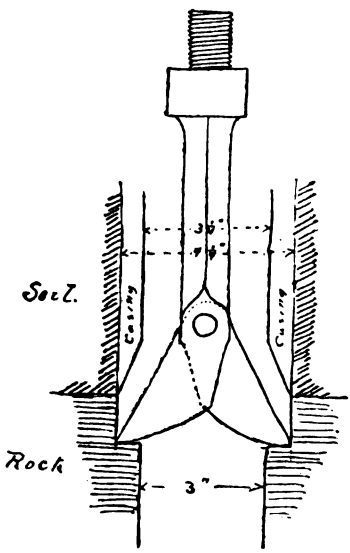
OBSTACLES AND SPECIAL APPLIANCES IN DRILLING.

A few difficulties are here described that are sometimes met with in drilling. The outfit that has been considered does not provide for overcoming all of them, as those difficulties requiring special appliances and are not of frequent occurrence. The method of overcoming these obstacles is here described in a general way.

If the soil contains small caving gravel, sand, etc., it can generally be pierced with the piping assisted with the auger.

Conglomerate or cement gravel can generally be pierced by the drill, but may tend to become loosened and fall into the hole and wedge the drill rods.

FIG. 19.



Expansion Drill.

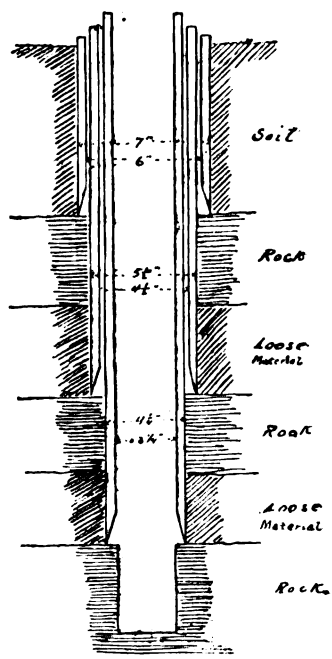
In either of the above cases, or where the gravel is large and caving, or if there are boulders present, it will generally be found necessary to sink a shaft to bed-rock.

It may occur that, after casing off the soil and drilling through rock, a considerable depth of loose material will be encountered. Either a shaft will have to be sunk from the surface down through the lower strata of loose material or else the 3-inch hole drilled in the rock is gone over with an expansion drill and enlarged suffi-

ciently so that the casing above can be driven through the rock and the lower bed of loose material.

Expansion Drill.—Fig. 19 shows one of the forms of expansion drills suitable for this work and its method of operation. The drilling bits are caused to spread to the desired gauge for drilling, either by their shape or by springs or by the action of the drill-rods.

FIG. 20.



Multiple Casing.

Multiple Casing.—Another plan is to sink casing pipe, 4½ or 4¾ inches inside diameter, through the first soil to the rock, and from there to drill a 4½-inch hole to the lower loose material, which will permit of entering the smaller casing pipe inside the larger casing and driving it through the lower strata of loose material to the rock, and the drilling of the 3-inch hole can then begin at that point.

If there are repetitions of the above formations, either the plan of expansive drilling or the plan of multiple casing can be used.

Fig. 20 shows the method of multiple casing through two strata of loose material below the surface.

Swelling clay slates are sometimes encountered which require continual reaming of the hole to prevent its closing.

Speed and Cost of Spring-Pole Drilling.

This will vary with the size of the hole and nature of the formations traversed.

The outfit considered has been for drilling a 3-inch hole, although similar outfits are arranged for drilling 1½ and 2-inch holes. The latter are adapted for shallow holes or for strata known in advance to be soft enough to be penetrated by a light-weight outfit.

The former outfit is preferable for general use, especially for the maximum depth of hole mentioned, or where some hard-drilling rocks are encountered, or if it should be found that, after starting to drill a 3-inch hole, that a strata of loose material exists below the rock, the hole will then be large enough to let a smaller casing pipe down in the 3-inch hole to the rock below, and from there drill a 1½ or 2-inch hole.

A 2-inch outfit can be readily operated by two men.

In Pennsylvania and Ohio spring-pole drilling of 1½-inch and 2-inch holes have in instances been driven at the rate of 8 to 10 feet a day for the first hundred feet and 4 to 8 feet a day for the second hundred feet. For holes averaging 150 to 180 feet deep the contract price is as low as 65 cents a foot from the surface, the contractor furnishing the outfit.

The strata in these cases are generally 10 to 30 feet of soil, with limestones, sandstones, slates and shales below.

In some instances of drilling 3-inch holes about 200 feet deep, the average rate of driving has been 6 feet a day, requiring 34 working days for completion, the speed being 7 to 8 feet a day for the first hundred feet and 4 to 5 feet a day for the second hundred feet. The contract price being 90 cents a foot from the surface, the outfit being provided for the contractor.

The speed of drilling in this instance is somewhat slow due to some hard flinty sandstones encountered. Following is given the section of the strata in which this drilling was done, 43 feet of surface soil and large loose gravel being excavated before drilling began.

	Feet.	Inches.
Soil and loose gravel,	43	0
Sandstone,	8	0
Slates and layers of soapstone,	56	0
Hard sandstone with slates,	49	0
Hard sandstone,	12	0
Slates,	8	0
Slates and hard sandstone,	14	0
Slates,	12	0
Hard sandstone and slates,	10	0
Coal,	1	0
Slates,	3	0
Coal,	3	6
Total depth,	219	6

As compared with diamond drill boring, 1¼-inch hole in similar formations, the following are the relative speeds:

Depth.	Number of Feet Drilled Daily.	
	Spring-Pole Drill, 3-Inch Hole.	Diamond Drill, 1¼-Inch Hole.
0 Feet to 100 Feet	7 to 8	20 to 18
100 " " 200 "	4 " 5	20 " 16
200 " " 300 "	3 " 4	18 " 14
300 " " 500 "	.....	16 " 14
500 " " 900 "	.....	14 " 10
900 " " 1000 "	.....	9

The average speed of boring a 1¼-inch diamond drill hole 200 feet deep is 18 to 20 feet a day or about 11 days for its completion. For an 800- or 900-foot hole the speed is 16 to 18 feet daily or about 43 to 49 days for its completion. For a 1000-foot hole the average speed will be about 15 feet daily or about 60 days for its completion.

The moving and erecting of the diamond drill from one location to another preparatory to operating, especially in rough countries, is more expensive than with the spring-pole outfit. Allowing 3 days for changing position in addition to 11 for drilling a 200-foot hole it will require about 14 days for drilling a 200-foot hole with changes of location, or about 24 holes 200 feet deep can be drilled yearly, equal to a total of 4800 to 5000 feet yearly.

About the same number of feet will be drilled in a year if the holes are of greater depth, say up to 900 or 1000 feet, in the case under comparison.

With the spring pole a 3-inch hole 200 feet deep would be completed in 34 days. Allowing one day for moving and erecting, about 35 days would be required to drill a 200-foot hole and change location, or about 8 or 9 holes 200 feet deep can be drilled yearly, equal to a total of 1800 feet yearly.

Following is given the comparative cost of drilling with the spring pole and the diamond drill in the case under consideration, where they have been operated under similar conditions:

Cost of Spring-Pole Outfit and Drilling.

Following is given the cost of a 3-inch spring-pole drilling outfit, including labor and material.

Drilling Tools.

Spring pole, cut and rigged,	$ 5 50	
Windlass, derrick, etc.,	14 75	
Lumber for platforms, casing, etc.,	3 00	
Ropes,	7 25	
250 feet of 1¼-inch by 1¼-inch iron for rods, 52 pounds per foot at 4 cents,	52 00	
Joints for rods,	30 50	
Special iron, steel, etc., for tools, 300 pounds at 6 cents,	18 00	
Forming and shaping special tools,	55 00	
Machinists' and other tools,	15 00	
		$201 00

Pipe-Casing Tools.

Pipe driver,	$ 4 50	
150 feet of 3¼-inch casing pipe, threaded at 75 cents a foot,	112 50	
Forming and shaping special tools,	15 00	
Machinists' and other tools,	15 00	
		$157 00
Total,		$358 00

The cost of moving, sharpening tools, repairs, etc., for each hole will be about as follows:

Moving, erecting, digging pit, etc.,	$ 7 50
Carpenter work, lumber, nails, etc.,	6 25
Blacksmithing, sharpening, repairs,	10 50
New ropes,	4 25
	$28 50

The daily cost of labor, drilling a 3-inch hole is as follows:

1 head driller,	$2 50
1 helper,	1 25
2 laborers at $1,	2 00
	$5 75

If 6 to 7 feet are drilled daily the cost per foot will be 82 to 96 cents for labor.

The total cost of drilling per foot will therefore be:

Interest on cost of outfit = 10 per cent. of $358 = $35.80 by 1800 feet per year =	$ 0 02
Cost of moving, sharpening, $28 50 ÷ 200 feet,	14
Cost of labor per foot or contract price per foot,	90
Total cost per foot,	$1 06

Cost of Diamond-Drill Boring.

Following is given the cost of drilling a 1¼-inch hole with diamond drill.

The daily cost of labor drilling:

1 foreman,	$ 4 00
1 helper,	2 50
2 laborers at $1.50,	3 00
1 driver,	1 00
1 team, hauling fuel and water,	1 50
Total,	$12 00

If 18 to 20 feet are drilled daily, the cost per foot will be 60 to 70 cents for labor.

The cost of dismantling, moving and erecting for each hole is as follows:

Drilling force, 3 days at $12,	$36 00
1 additional team 3 days at $1.50,	4 50
Total,	$40 50

The total cost of drilling per foot will therefore be as follows:

Interest on cost of diamond-drill outfit, estimated at $5000 at 10 per cent. = $500 ÷ 5000 feet per year,	$0 10
Labor drilling, $12 ÷ 18 feet daily,	70
Moving, erecting, etc.; $40.50 ÷ 200 feet,	20
Fuel and water, $2 50 daily ÷ 18 feet,	14
Diamonds, 24 karats yearly at $16 a karat = $384 for 5000 feet, or .0048 karats per foot at $16,	07
Repairs to boiler and machinery about $200 yearly,	04
Total cost per foot,	$1 25

Provided there was a sufficient amount of drilling to soon absorb the first cost of a diamond-drill outfit, and other conditions were favorable, the cost of diamond-drill boring per foot will not greatly exceed that of spring-pole drilling.

If fuel and water are scarce, this item of cost as above shown, will be greatly increased.

In conclusion, the conditions first mentioned governing the use of the spring pole are: 1. Where only a small amount of drilling is to be done. 2. If only moderate cost is to be incurred. 3. If great speed is not required.