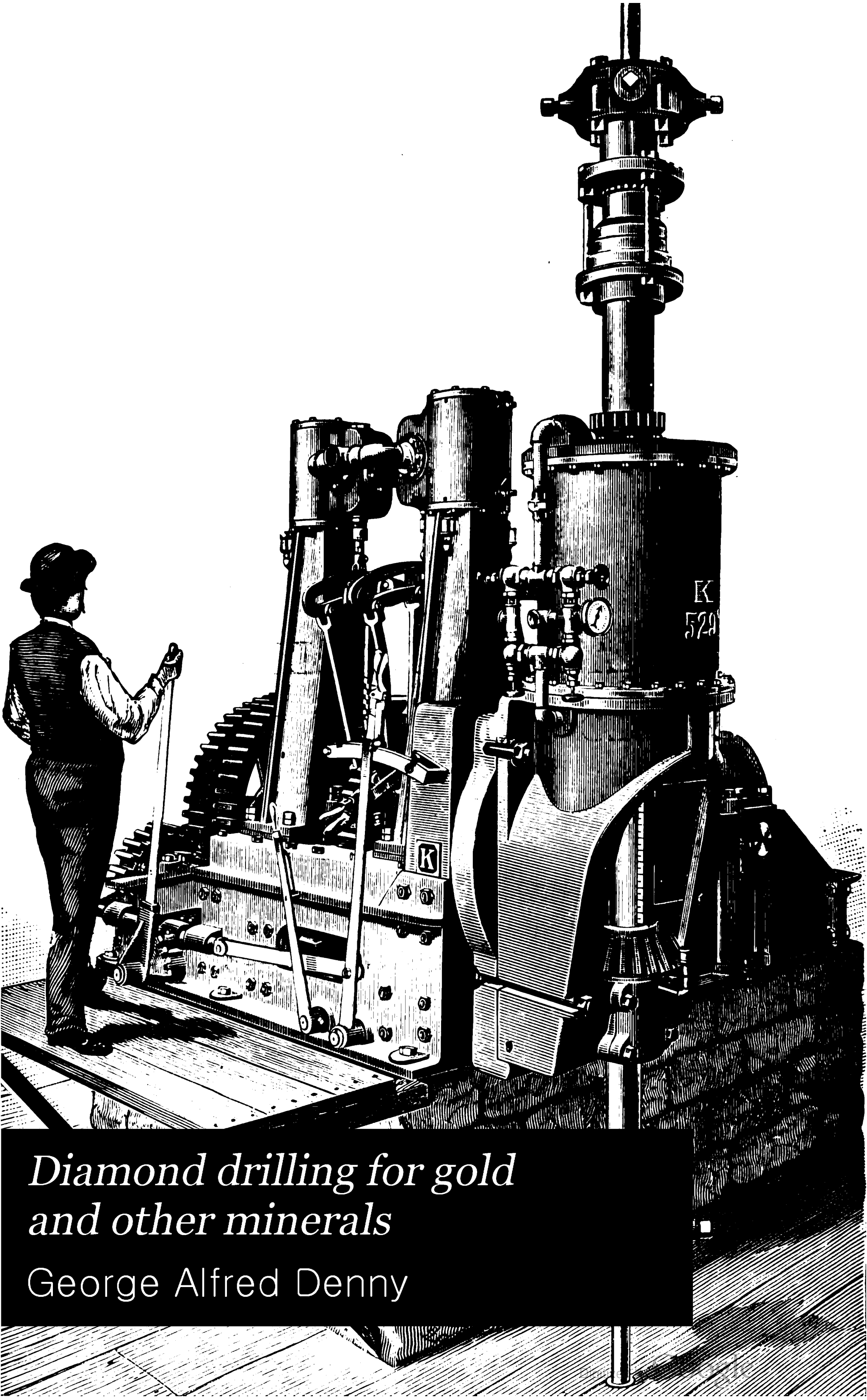
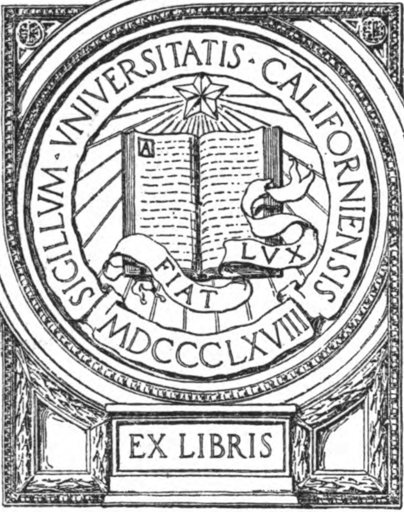
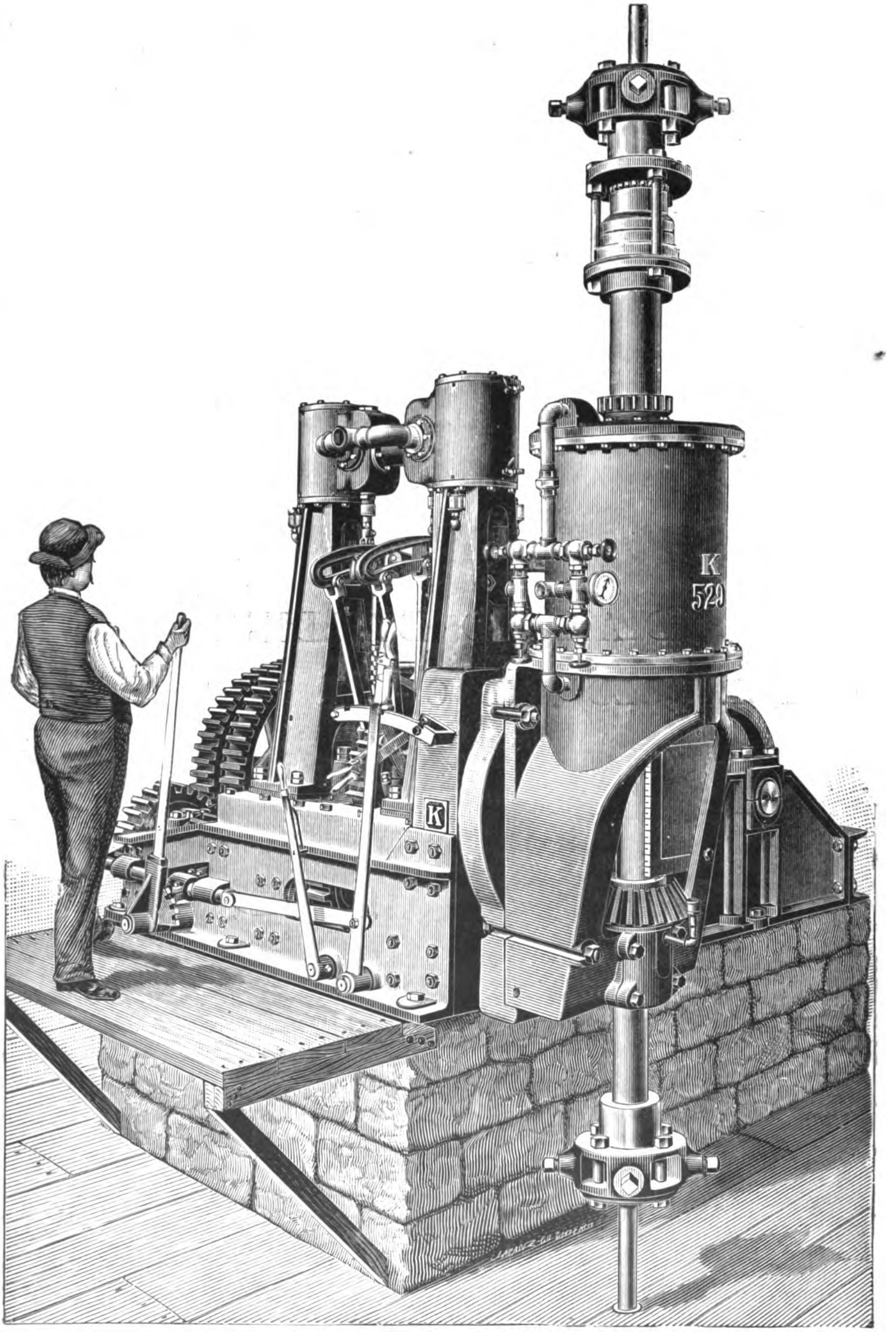


Diamond drilling for gold and other minerals

George Alfred Denny



DIAMOND DRILLING
FOR GOLD AND OTHER MINERALS



The Sullivan Diamond Core Drill, Size K (see p. 103).

[*Frontispiece.*

DIAMOND DRILLING
FOR GOLD AND OTHER MINERALS

A PRACTICAL HANDBOOK ON
THE USE OF MODERN DIAMOND CORE DRILLS IN PROSPECTING
AND EXPLOITING MINERAL-BEARING PROPERTIES

INCLUDING

PARTICULARS OF THE COST OF APPARATUS AND OF WORKING

BY

G. A. DENNY

MEMBER OF THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS
MEMBER OF THE LONDON INSTITUTE OF MINING AND METALLURGY
AND MEMBER OF THE AMERICAN AND AUSTRALIAN INSTITUTES OF MINING ENGINEERS
CONSULTING ENGINEER TO THE GENERAL MINING AND FINANCE CORPORATION, LIMITED, OF LONDON
AUTHOR OF "THE KLERKSDORP GOLDFIELDS"

With Illustrative Diagrams

LONDON
CROSBY LOCKWOOD AND SON
7, STATIONERS' HALL COURT, LUDGATE HILL
1900

PREFACE.

THE rapid strides made in recent years in the perfecting of the Diamond Drill, and its now general use in prospecting for mineral and metalliferous deposits, have created a want in technical literature which it is the purpose of this work in some measure to fill.

The greater part of the work having been written in the Transvaal, and with the special features there existent before the mind of the Author, his aim has been, whilst including much information which is generally applicable, to make the work more particularly adapted to the needs of South African diamond drillers and of other persons who may be contemplating the use of diamond drilling machines in connection with the prospecting or exploitation of mineral lands in South Africa.

The general matter contained in the work being derived from the recorded observations of a wide experience in diamond drilling, the Author trusts that it will commend itself equally to the diamond driller, to the general reader, and to others who may be in search of reliable information upon the subject. He feels, also, that no apology is needed for a conscientious effort to contribute, in a handy form, what he believes to be the first exposition of the nature and use of modern Diamond Drills. He is aware that there are other Diamond Drills on the market besides those referred to in this volume, but he has dealt with those only of which he has had actual experience.

In the Appendix (pp. 137—158) there will be found various particulars relating to both the Sullivan and the Bullock Diamond Drills, and the special Tools and Supplies required therewith, which will be found useful by intending purchasers of such appliances.

Acknowledgment is due, and is hereby tendered, to the firms who have so obligingly placed their catalogues, cuts, etc., at the Author's disposal. From the materials thus supplied, details of the different drills, as well as other data and information suitable for the work in hand, have been freely extracted.

The Author has also to thank Mr. Bennett H. Brough for his courtesy in sanctioning the two full quotations from his "Treatise on Mine-Surveying," which will be found at pages 76 and 95, respectively, of this volume.

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DIAMOND DRILLING.

CHAPTER I.

INTRODUCTORY.

The business of gold mining is being rapidly evolved from the sometime blindly speculative to a legitimate commercial enterprise, in which it is clearly recognized that the increased profit potentialities compensate for certain added risks which are involved in its prosecution. From its very nature it is frequently impossible with any degree of certainty to estimate what result may be expected from a given mining venture.

The uncertainties are primarily (1) the average milling grade of the ore; and (2) its width and extent. The manner of settlement of these has too often in the past been upon lines which are not to be recommended in any way. In the case of a company possessing a reef outcrop, it has been thought sufficient to take a few specimens of the reef at surface; ascertain their value; and establish from that a basis of calculation from which is deduced the worth of the entire holding. Shafts are sunk, a mill is erected, and everything proceeds satisfactorily until milling begins. A result totally disappointing and absolutely unpayable is obtained. The company suspends operations, and, may be, a promising district is blighted.

The reason for this, leaving premeditated fraud out of the question, is perfectly clear; the ultimate result is only that which would be attained by similar procedure in any ordinary commercial business. A manufacturing firm, for instance, only goes into production when its fields of demand have been prospected by those means which industrialism provides. Its entire resources are not launched into a business until its full nature is understood and its potentialities have been gauged. If this is necessary in a mercantile business, where the factors which primarily enter into its successful career may be approximately ascertained, how much more is it necessary in the business of gold mining, where these are only ascertainable by actual experience in each case?

This brings us to the question of the means to be employed for the legitimate settlement of those uncertainties which we have before stated to be primarily—

1. The average milling grade of the ore;
2. Its width and extent.

To this we reply that one commendable method is that of systematically prospecting the auriferous strata by diamond core drills, which, in themselves comparatively inexpensive, secure to the operator a true outline view of what he may expect more expensive and extensive mine development will disclose.

It is a well-established fact that the only reliable and satisfactory method of drilling prospect holes is by means of diamond core drills. These have entirely superseded the churn drill, which proved in many cases absolutely valueless. Instances might be given in which large sums of money have been literally thrown away in sinking shafts for coal on the records furnished by churn drills, wherein the supposed seam of coal proved to be nothing but a black bituminous shale.

The diamond drill bores a perfectly smooth hole to any depth or in any given direction from vertical to horizontal, bringing to the surface a solid section or "core" of all strata passed through, in the order in which they lie, determining also the exact depth of any particular rock, its thickness and characteristics. The size of the core, which varies from 1 to 6 inches, according to the nature of the formation under operation, allows of thorough examination and testing, and the presence or otherwise of the ore or mineral sought is settled beyond a doubt. It also gives positive information of the rock that will be met with in the shaft sinking, thus making it possible to closely estimate the cost of such work.

The requirements of a diamond drilling machine are many and exacting. It must be strong, simple and durable, economical in the use of steam and in the wear of diamonds, rapid in operation, and above all, its work must be accurate and reliable, so that the results derived from it shall be known to be correct, as upon them depends the expensive processes of shaft-sinking and equipment, as well as the investment of large sums of money in land.

Not only for prospecting from surface, but for many other uses, as drilling in advance of levels underground, in sinking for gas, oil, or water, and in submarine work, the diamond drill is called into requisition.

I purpose to deal, therefore, with the applicability of diamond-drilling in the prospecting of auriferous strata, stating the arguments for and against; and further, to describe well-known types of drills, contrasting their differences and comparing their respective merits, finally describing the operation of diamond-drilling and giving hints in that connection.

CHAPTER II.

APPLICABILITY OF DIAMOND DRILLING TO AURIFEROUS DEPOSITS.

Auriferous deposits may be classified in four leading divisions:—

1. As interstratified beds.
2. As filling pre-existing fissures whose course may be through rocks of different structure.
3. As segregated deposits in rocks of igneous origin.
4. As alluvial or placer deposits of Tertiary age.

The rocks included in the first classification are notably represented by the "banket beds" of South Africa, which are of aqueous origin, and are generally found intercalated amongst the Devonian sandstones and grits of the country.

The rocks of the second division are illustrated in the well-known quartz reefs, which are common to all countries.

The third division includes segregated deposits of auriferous quartz, within rocks which have themselves furnished both the silica and the gold. This division is illustrated in the auriferous segregations in (*a*) Diorite at Walhalla, Victoria, Australia; (*b*) Tertiary trachytes in many parts of New Zealand; (*c*) Dacite in Transylvania.

The fourth division includes the auriferous wash of Australia, California, and many other countries.

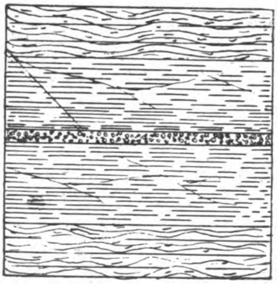

FIG. 1.

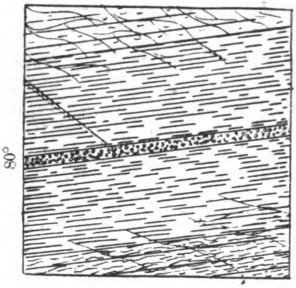

FIG. 2.

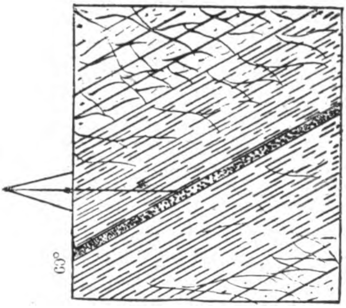

FIG. 3.

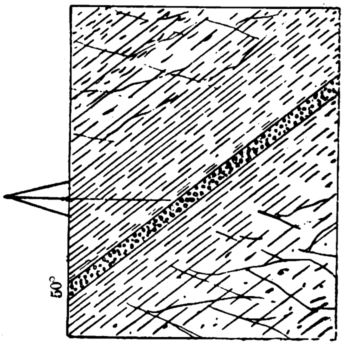

FIG. 4.

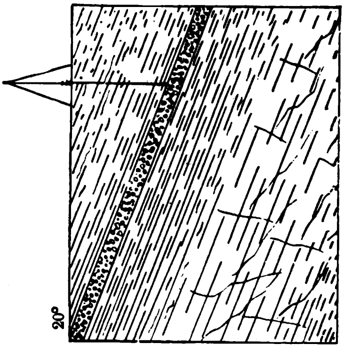

FIG. 5.

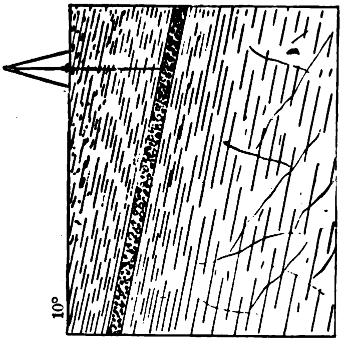

FIG. 6.

DIAGRAMS ILLUSTRATING DISPOSITION OF STRATA.

Diamond drilling is applicable to the prospecting of any auriferous deposit—directly as to its horizontality, and inversely to as its verticality—for the following reasons. Let Figs. 1, 2, 3, 4, 5, 6 represent strata which range from vertical to an angle from the horizontal of 10 degrees. In Fig. 7 assume the outcrop of the reef to be at the point A, then the varying figures

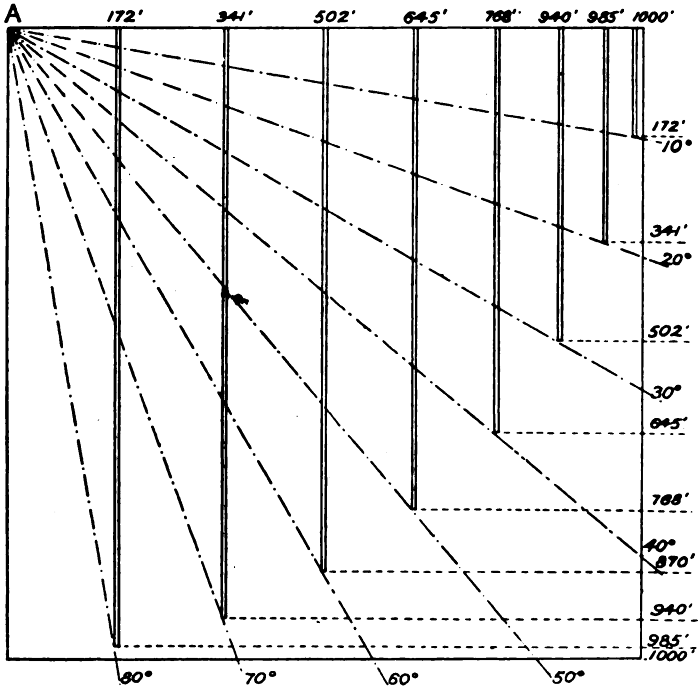

Fig. 7.—Illustrating Position of Drill in relation to Strata.

induced by changes in the dip are shown, the horizontal distances indicating the position of the drill, and the vertical distances indicating the depths of holes 1,000 feet on incline, from outcrop, on reefs ranging from 10 to 80 degrees dip.

Let us assume that it is desired to prospect vertical strata by diamond drill, and that the exact location of the reef or auriferous zone is not easily to be found. The drill would then be placed as shown in Fig. 8, and inclined holes would be bored to intersect the reef.

The cost to strike a reef under such conditions would naturally be increased by the greater number of feet

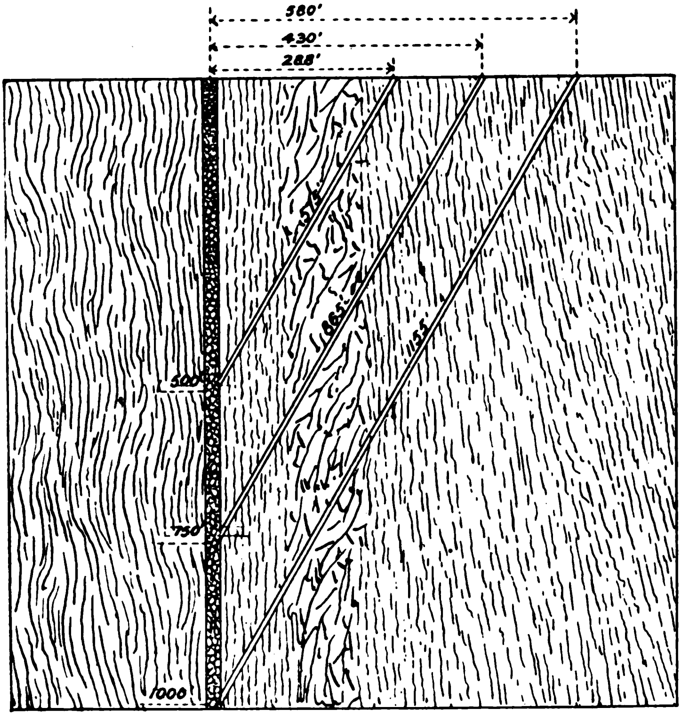

Fig. 8.—Illustrating Position of Drill in relation to Strata.

which it would be necessary to bore in order to reach the point sought. It may be argued that a hole very slightly off the vertical might be bored which would not materially increase the depth as compared with vertical boring. Theoretically such an argument is unanswerable; in practice, however, it is found that holes bored on the incline rarely keep a true projection, the tendency being to deviate proportionately to the depth of the hole. Further, a reef, though absolutely vertical at surface, cannot be relied on to retain a truly perpendicular course; therefore it would be possible in many cases to entirely miss it. A hole inclining to the reef at an angle of 60 degrees would meet most conditions to the best advantage. If it were required to test the value of the reef a further 500 feet from the outcrop—that is, 1,000 feet perpendicularly in this vertical reef—it is obvious that a proportionately longer hole would be required to intersect it than would be necessary if the reef were inclined. Naturally, if a reef were very wide, and were standing vertically, the easiest method would be to bore a hole into it vertically. I have, however, assumed that no reef is visible, and hence the necessity arrives for proving the existence, or otherwise, of one in depth.

It follows from these observations that an auriferous formation which seldom attains verticality, and whose average is from 30 to 40 degrees from the horizontal, offers the greatest facilities for prospecting by the means we have under discussion.

In every instance I premise the existence of fuel and water supply; failing these, diamond drilling is impracticable.

In the classification of auriferous strata which we have made we are dealing with ore deposits of two kinds:—

1. Such as owe their origin absolutely to aqueous agencies.

2. Such as are dependent for origin upon hypogeic forces.

In the first case we have as illustration the banket beds of South Africa, and the alluvial deposits common to all countries, which latter we shall at present leave out of consideration.

The banket beds, after being horizontally deposited, have, in most instances, subsequently been uptilted through subsidence, owing to contraction of the earth's inner nucleus, and have been directly lifted by igneous eruptive action into varying angles from the horizontal. The banket formation of Africa, so acted on, does not exceed an average angle of 30 degrees at a distance of 2,000 feet on the incline from the outcrop. In the Klerksdorp district of the Transvaal the average is considerably under this, probably not exceeding 15 degrees from the horizontal.

In the case of quartz veins and segregated deposits in igneous rocks, it is usually found that they affect verticality or angles approaching to that.

It may be stated then, at the outset, that the banket formation, from a stratigraphical standpoint, is one that lends itself peculiarly to prospecting by diamond drill, and though the same principle may be applied to quartz veins and segregated deposits, it is only exceptionally that it can be recommended. We may now, however, state a further important feature of the applicability of this mode of prospecting to banket formation, in this case one having strict relation to the character of the gold impregnation. In another work by the writer ("The Klerksdorp Gold Fields") it is shown that banket beds are not, from their very nature, liable to the fluctuation in gold content, to which, similarly from their very nature, quartz veins and segregated deposits are.*

The first-named have been abundantly proved—by the unprecedented development in the Witwatersrand district—to contain gold in very fairly average and constant quantity, along a strike distance of about 40 miles. In the dip direction the permanency of the beds has been proved by boreholes to a depth of 6,500 feet on the incline, from outcrop. There is, unquestionably, in all banket beds a tendency to variation in tenor, or, in other words, they contain rich and poor patches; but these occur promiscuously, and are within such limited areas, as from patch to patch, that for all intents and purposes they may be regarded as one grand whole, whose integers are easily determinable and definable by systematic mine development.

Quartz veins are liable to variation in tenor, precisely in relation to the zones which have afforded a passage to percolating gold solutions, or to the character of rock which may at the moment form the "country."

In exploiting quartz veins it is found that the pay ore is confined to certain shoots, which may or may not have a defined direction, and are usually limited in width to, say, from 100 to 500 feet on the strike.

A given quartz reef contains possibly only one payable shoot in miles of length, whilst another may have shoots occurring at irregular distances. It is perfectly obvious

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* I here exclude the Black Reef, which presents so many special features, principally of age and deposition, that it may be relegated to the class of exceptional cases.

that diamond drilling has but limited application in cases of this kind.

In the instance of segregated deposits the same argument is even more strongly applicable. The direction and location of the segregated pay ore is entirely a matter of local conditions, which may here affect a zone 500 feet wide, and there, not far distant, be only 5 feet in width. Manifestly these conditions—speaking strictly of surface deposits—are quite adverse to the general application of the diamond drill, though in special cases, both in the case of quartz reefs and of segregated deposits, its suitability is not prohibited.

We have, therefore, established so far the following premises:—

1. That banket beds, because of their general average inclination at angles between 15 and 30 degrees, and because of the evenness of their gold tenor, are particularly suitable for diamond drill prospecting.
2. That quartz reefs and segregated deposits, on account of their generally high angles of inclination, and their localised pay zones, are only in special cases advisedly superficially prospected by diamond drills.

THE FUNCTION OF DIAMOND DRILLING IN RELATION TO THE DEVELOPMENT OF MINING PROPERTY.

Let us assume that we have a property which is the "dip" portion of a known reef.

Assume, in the first instance, that it is decided to begin shaft sinking without recourse to Diamond Drills. The objections to this method are :—

1. Initiation of operations without any accurate figures as to the positions of the reefs and the estimated time to reach them;
2. A blind guess as to the shaft equipment required;
3. No accurate data as to the cost of the work proposed.

If, on the other hand, diamond drilling be instituted, all the objections just named are removed, and the first crosscut may be started from the shaft to intersect the reef with every certainty of getting it, and thus eventually the reef will be struck in the first crosscut and the shaft at about the same time, saving the delay which is occasioned when the first crosscut is located after striking the reef in the shaft.

If, of course, we are dealing with unexplored ore deposits in which (1) the average milling-grade of the ore and (2) its width and extent have not been settled at any point, then prudence demands a settlement of these within approximately accurate lines by diamond drilling before the heavy expense attaching to shaft sinking methods is determined upon.

It is clear to the mind of the writer that diamond drilling and shaft sinking on deposits of unknown value are not comparable methods, and that each has its own separate function to peform for the attainment of the object desired.

So far, however, we have only dealt with the comparative values of the two methods upon reefs whose outcrops are visible and continuous. We have now to consider the case of reefs which have been faulted, and whose outcropping portions may, therefore, although keeping a parallel direction, be considerably out of line.

The first site of a shaft or borehole may easily, under these conditions, be entirely out of the true strike of the formation which is sought, so that it may be necessary to try at several points before the location is successfully made. Under this aspect, therefore, there can be no question that diamond drilling is superior to shaft sinking, because (1) the location may be earlier established, and (2) the work may be performed at 20 per cent. of the cost of sinking.

Diamond drilling may, therefore, be regarded as a means to an end; and that end being obtained with satisfactory issue, there remains no other method of further development than the process of mining, which is, in its initial stages, shaft sinking. If, for instance, it is decided to sink a shaft at a long distance from the outcrop, upon a banket series whose average grade has been proved, and if faults exist between the points chosen and the said outcrop, and it cannot be reckoned with certainty whether the reef is downthrown or upthrown, a borehole will quickly and satisfactorily settle the question, with which knowledge the hoisting equipment may with certainty be laid down, obviating the dangers of too light or over-heavy equipment; which are present if the true depth of the shaft be not known beforehand.

The objections that are made against diamond drilling in the abstract are of the following nature :—

1. The drill may strike a very thin and poor section of the reef.
2. It may intersect the reef at a point where it is far above the average width or value.
3. There is a liability to grind the softer portions of a reef—which may be the richest—to powder, and therefore no core, would be obtained from that particular portion, hence possibly causing the condemnation of a good property.

These objections, though *primâ facie* quite valid, have no weight when the requirements of a regular diamond-drilling policy are laid. Such requirements include the following stipulations:—

1. That the reef is intersected at a certain number of points to enable an average of the existing features to be drawn.
2. That proper precautions are taken to settle the fine material returned by the pump, which represents any lost percentage of core, plus the actual cutting of the diamond crown. The separate samples of the settlings should be made at short intervals, when it is suspected that the drill is boring in the neighbourhood of valuable reefs.

   The latter precaution has been found, however, after many trials, to be quite superfluous upon the banket formation of South Africa, for the reason that at a comparatively shallow depth from surface the ore is quite unoxidised, and therefore is only liable to be affected by the triturating action engendered in the core-barrel, in cases of an abnormal percentage of pyrites.

It is patent that reliance on one borehole, be the results satisfactory or otherwise, is quite unwarranted, since it means that one inch in section is taken to represent the average of areas whose dimensions are named by acres. Even in the richest mine there are portions which might be bored through, yielding unpayable results; and similarly, in a poor deposit, a rich portion might be struck, whose value would be very misleading if taken as an average of the whole.*

It is necessary, therefore, in order to obtain a true interpretation of the features of a given deposit, that it be intersected by a series of boreholes, and that the information thus obtained be averaged over the whole area included within the borings. If performed in this manner, I have no hesitation in asserting that the objections noticed are abolished.

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* In this connection I recall an instance some years ago in Australia, in which a hole was bored to prospect for a rich shoot in a quartz reef on an adjoining property. At a depth of about 700 feet the drill entered a quartz reef, and a core about 10 feet long resulted, which assayed 2 ozs. per ton. On the assumption that the reef was proved to be valuable, a working shaft was sunk at some little distance from the borehole site, and in course of time reached the required depth, but no reef was found to exist. The company then determined to drive for the borehole, for the purpose of discovering whether a fraud had been perpetrated. It was found that the drill had entered a nearly vertical leader about 2 inches in width, which it followed for 10 feet before cutting through into the country rock. It is difficult to understand how it was that the fact of the core being only a portion of a thin seam was not realised, seeing that there must have been a gradual passage from the slate-country rock into the quartz in the first place, and from quartz to slate in the second. The fact remains that it was unnoticed, and that on the strength of the result obtained from the one borehole a large sum was expended in shaft sinking.

APPLICABILITY OF DIAMOND DRILLS TO UNDERGROUND PROSPECTING.

In some countries the practice of seeking for lost ore bodies, and prospecting for new bunches or shoots of ore, is performed by the diamond drill. This method of prospecting is, however, resorted to chiefly where ore bodies occur in more or less scattered bunches or impregnations, as deposit of silver and lead ore in limestone. In such cases the running of a heading purely prospectively is a very precarious and costly undertaking, since it cannot with any certainty be conjectured in what position the ore sought may be, or even whether it has any existence. The diamond drill is particularly applicable in such circumstances, because (1) of the lesser cost, and (2) of the accelerated rate of advance, and therefore the earlier knowledge of the value of ore in the pierced zone.

Whilst admitting that its uses are less adapted to the condition of ordinary metalliferous deposits, the writer is still of the opinion that there is a very useful field open for it in the conditions which obtain in almost all mines on the banket deposits of the Transvaal. Here, however, the phenomena requiring elucidation are not, as in the instance earlier mentioned, the position of scattered ore bunches which owe their origin and condition to a locally excited chemical cause, but the locale of entire series of rocks shifted out of their normal position by hypogeic forces.

The application of Schmidt's law of faults to the dislocations of the banket series of the Transvaal has, in almost every instance that has come under the writer's notice, pointed to the direction of the throw, and if this law were universally applied there would be very few instances of inaccuracy in conclusions arrived at from its application. As, however, the majority of miners scorn trigonometric formulæ in connection with their daily work, rule-of-thumb methods are depended upon for the solution of the problems indicated.

In such cases it is usual to begin a crosscut in the direction in which it is supposed the faulted reef now lies. Frequently it happens that the crosscutting reveals nothing, and the miner, seeing that his rule-of-thumb method has failed him, is forced to guess the direction.

Here is the opportunity for the diamond drill, as by its use holes in any direction may be bored, and the reef location established more quickly and cheaply than by blasting crosscuts. The work let on contract would cost, say, 20s. per foot, for lengths up to 500 feet. Assume that the drill fails to discover the ore body—proving the faultiness of the premises taken in setting it out—and contrast the cost in time with these items if the distance had been traversed by crosscutting.

A machine rock drill, skilfully handled, would drive, say, 20 to 25 feet per week in hard pyritic quartzites, equal to 25 weeks for the distance above named. The cost to perform this would average say, 55s. per foot inclusive on a mine with a mill in operation. Therefore the crosscut would be completed in 25 weeks at a cost of £1,375.

The rate of advance by diamond drill may be placed at

300 feet per month. Thus the total distance would be run in, say, seven weeks, at a cost of £500.

In the circumstances named, therefore, three holes in different directions might be bored, and the fullest information obtained with the diamond drill, whilst with the rock drill, in the same time, only one section would have been explored.

The Sullivan Diamond Drill manufacturers, in view of the increased demand for an underground drill, compact, and of the necessary power for boring holes of any likely depth and at any angle, have perfected an electrically-driven machine, illustrated in Fig. 9. This company has recognised that one of the drawbacks in the adoption of the diamond drill underground has been in connection with the motive power of the machine, steam being almost impracticable and compressed air very costly.

To overcome the difficulties and drawbacks attendant upon the use of steam or compressed air, they have designed the machine already mentioned.

Electric power is now such a common feature in mining operations, for hoisting, pumping, and lighting, that every well-equipped mine is provided with modern electric power-generating machines.

For operating the electric drill, any continuous electric current of sufficiently low voltage for safe use underground may be employed, provided it delivers three-horse-power to the motor attached to the drill.

The motor for driving the drill is mounted with it on the one frame, as are also a pump and hoisting-drum with wire rope, so that drill, motor, pump, and hoisting apparatus form one combined whole, which may be easily mounted on a truck for removal to different points in the mine.

The friction feed, elsewhere described, is used with this drill, but is mounted on a different style of frame.

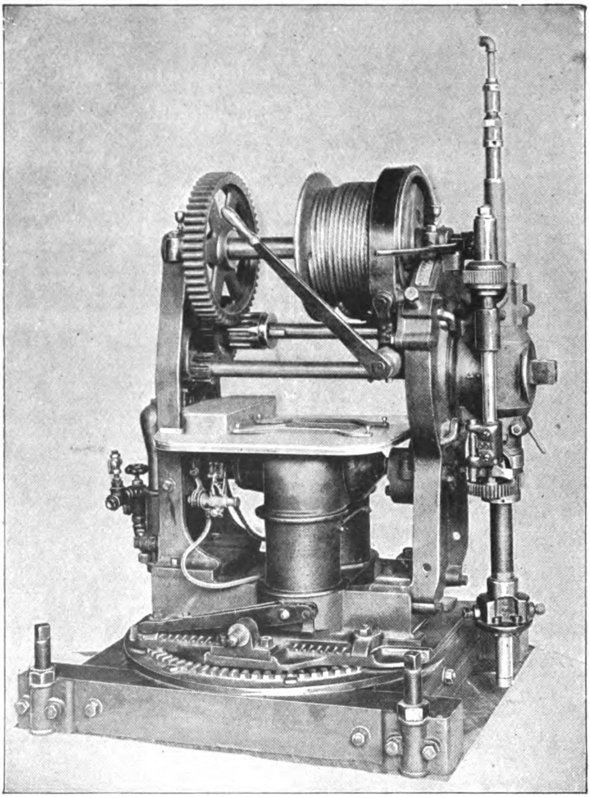

FIG. 9.—ELECTRICALLY-DRIVEN SULLIVAN DIAMOND DRILL.

Switches, resistance-box, etc., are provided for safety and convenience, and the parts of the machine are insulated, so that the drill may be used in wet mines.

The machine is mounted on a swivel base, so that holes may be drilled in any direction, or at any angle, without moving it from position. The hoisting-drum is placed in line with the armature, so that the rope pulls directly in line with the drill-hole.

An extract from the report of Professor Lewis C. Hill, State School of Mines, Golden, Colorado, in connection with a Sullivan electric drill in use at Aspen, is worthy of mention, as showing the performance and cost of running the machine. He says:—

"This drill takes about 3 ampères, at 440 volts, as an average, with a short drill-rod; and a maximum of 8 ampères, at full speed, in exceptionally bad ground. A safe average of the drill is from 3½ to 4 ampères, or from 2 to 2¼ horse-power. The speed of drilling was given as 45 feet per day of 20 hours, as an average of 5 months' run. The cost of drilling, exclusive of power, was put at 45 cents. The operating expenses of the plant are about 12 dollars per month per horse-power, or 2 cents per horse-power per hour, figured on a basis of 25 horse-power. The wages of two attendants comprise, of course, almost the entire cost."

This machine, running in the hard quartzites characteristic of the Transvaal mines, would probably effect a performance of 300 feet a month at a cost of from 15s. to 25s. per foot, depending upon the price of carbons.

CHAPTER III.

HAND-POWER DRILLS.

THE Sullivan and Bullock Companies each manufacture a well-designed hand-power machine, whose essential difference is—as in the respective power machines—in the feed apparatus.

The Bullock Company applies its positive feed-gear to the hand machine, as to the power machine; proportioning, of course, the rate of feed to the speed and capacity of the machine.

The Sullivan Company applies its special friction-feed to the hand machine which it supplies, which feed, as we elsewhere show, possesses superior advantages over the "positive" for this class of work.

As, however, the Bullock hand machine is most generally used in South Africa, it shall be given more prominent mention.

APPLICABILITY OF HAND DRILLING.

The hardness of the rocks constituting, and of those stratigraphically related to, the auriferous formation of South Africa, is such, that it is only when great pressure is exerted through and upon the diamond cutting-bit that any sensible progress is made in boring them. Of the various types of hand drill which are manufactured there is no doubt that the positive and friction feed types are superior to those whose pressure is obtained through suspended weights. This is manifest. In the one instance the feed is forced forward by positive or frictional mechanical action, in the other only the force which a suspended weight can be brought to bear is obtainable. The conditions are, therefore, that in the first instance, so long as the power operating the machine is able to overcome the friction of the diamond crown against the rock under process of cutting, there is a regular advancement governed by the speed to which the feed-gear is set. In the second instance there is no forward positive feed, and therefore the diamonds simply polish a surface upon the face of the stone, and a purely infinitesimal cutting is made. The writer has known instances of this type of drill, where the work performed during a continuous eight hours run was less than one-fourth of an inch.

The rate of progress of the positive feed type is, as before stated, entirely regulated by the feed-gear, and by the speed that the machine is run. Upon banket rock series, however, the friction is so great that the work is made very laborious, and constant changes of men are necessary. This means, practically, that double the labour is necessary for the work, and costs are to that extent increased,

Summarising the experience of hand drills in banket formation, it has been found that—

1. The progress is very slow.
2. The work is exceedingly laborious.
3. The costs are excessively high.

In coal formation and for shallow depths hand drilling is thoroughly applicable, and will give satisfactory results; in rocks which have the hardness of quartz it is worse than useless to attempt prospecting with any hope of speedy issue. As, however, many Bullock hand machines are in use in this country, the following description and mode of operation is appended.

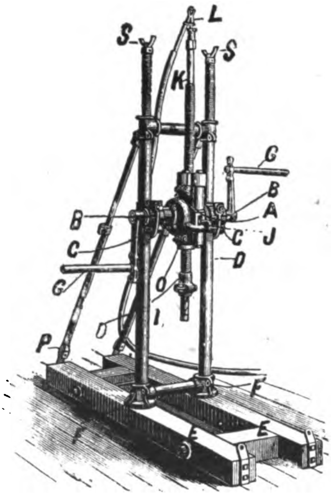

FIG. 10.—BULLOCK HAND-DRILL.

METHOD OF OPERATION OF THE BULLOCK HAND-DRILL.

After setting the frame in the position as shown in Fig. 10, place the feed J in the middle position, holding the feed nut O below the frame by a wrench. Turn the feed-screw left-handed by means of the handles and run it up until the chuck I just clears the feed nut O. Insert a length of drill-rod K through the feed and to the upper end attach the water-swivel L, and to the lower end the core-barrel, core-lifter and bit. Extend the drill-rod through the feed-screw until the bit nearly touches the rock to be bored, and fasten it in that position, with the chuck. Move the feed-adjuster to either its upper or lower positions—upper for slow, and lower for fast speed; start the pump, which is connected to the water-swivel, and see that the water flows out freely from the drilling-bit. Place the safety-clamp on the ground, so that the rods pass through it, turn the feed-screw right-handed by means of the handles, and the bit will feed forward.

When a full run is made—that is, when the top end of the feed-screw reaches the top of the drill-frame—loosen the chuck-nuts, move the shifter J to central position, turn the feed-screw left-handed, and it will run to the top of its stroke as before. Tighten the clamp, adjust the rate of speed, start the pump, and proceed as before.

When it is necessary to raise the rods to examine the bit or to take out core, stop the machine, and keep the pump working until all sediment or cuttings are removed from the hole. Attach the hoisting-rope to the top of the water-swivel and hoist the rods sufficiently high to get a joint above the safety-clamp and there secure them by its means; unscrew the length of rods above the clamp and hoist them out of the feed-screw. Now remove the drill proper from the columns, screw the hoisting-plug into the top of the rods held by the safety-clamp, attach the rope, tighten the rope to take the weight of rods, and loosen the safety-clamp. Then hoist the rods, and break the joint as before described, continuing the operation till all the rods are lifted. Remove the core-barrel, and unscrew the core-lifter, and the core will slip out of the barrel.

After the rods are lowered nearly to the bottom of hole, start the pump to loosen any sediment which may have settled; when this is clear, lower the rods to the bottom and restart boring.

Subjoined are particulars of the Bullock Manufacturing Company's hand-power diamond drill, Bravo, Class B., styled by them the "Prospector's Friend."

For gold and silver.
Diameter of bit, $1\frac{3}{8}$ inch.
Diameter of core, $\frac{15}{16}$ inch.
Depth of hole, 400 feet.

For iron, coal, etc.
Diameter of bit, $1\frac{3}{4}$ inch.
Diameter of core, $\frac{13}{16}$ inches.
Depth of hole, 350 feet.

This drill takes out a solid cylindrical core, showing an exact section of all strata penetrated.

The machine without columns only weighs 120 lbs., which can readily be divided into small packages of 20 lbs. or less, for transportation by men or mule-back. This is very important to prospectors, for it places within their reach a light, durable drill, which can be economically and successfully operated by hand or horse power, in localities which are inaccessible to other styles of drills.

The special features of the drill are as follow:—

1. The feed-screw is constructed so as to pass the drill-rods through it, they being retained by a chuck, thus allowing the placing of the drill close to the wall or workings, utilizing the full run of the screw, without causing the delay and trouble of attaching short lengths of drill-rods for each run.

2. The bearings for the feed-screw are very large, and the feed-nut is contained between frictionless balls or washers, which receive the thrust of the spindle or

weight of the rods, thus greatly reducing the friction and power required to operate.

3. The operating gears are all cut, and the moving parts balanced, thus insuring easy and even running.

4. The gears, feed-nut, and counter-shaft are neatly housed to protect them from dirt and injury.

5. There are two sets of feed-gears (a fast and slow) mounted on the feed-screw and counter-shaft, and, by means of the shifting-lever, engagement with either can be instantly effected, or they can both be thrown out of gear, thus quickly taking advantage of the hardness of the formations bored, without stopping the revolving of the feed-screw. There is also a friction-attachment, to moderate the strain or shock caused by these changes, or in boring in broken or varied materials.

6. The drill is mounted upon two columns by adjustable hinged bearings, by which it can be quickly secured or clamped at any height or angle desired.

7. The columns are secured to a wooden frame by hinged castings, allowing them to be inclined or laid upon the frame.

8. The frame also forms a support for the drill columns.

9. The columns are further supported by extension back legs; by placing weights other than that of the operators upon this frame, stability of the whole machine is obtained upon a sound base.

10. The drill, while placed upon a line centrally between the columns, is in front of these supports, thus affording free and easy access to manipulate the chuck, "safety-clamp," or tongs.

By simply removing the drill from its bearings hoisting is unimpeded.

The Bravo, unless otherwise ordered, is furnished with the following outfit:—

1 spare $1\frac{3}{4}$-inch bit set with diamonds.
2 $1\frac{3}{4}$-inch bit-blanks.
1 $1\frac{3}{4}$-inch bit-holder.
1 $1\frac{3}{4}$-inch core-lifter complete, and 1 extra ring.
1 $1\frac{3}{4}$ by 20-inch core-barrel.
1 $1\frac{3}{4}$ by 8-inch core-barrel.
1 combination water-joint and hoist-plug.
1 plain hoisting-plug.
12 feet $\frac{1}{2}$-inch water-hose.
12 feet 1-inch suction-hose and strainer.
1 pair each No. 2 and No. 3 Brown's pipe-tongs.
1 12-inch screw-wrench.
1 15-inch combination pipe-wrench.
1 double-end fork-wrench.
1 spanner-wrench.
1 lever-pump.
1 malleable oiler.
1 gallon wood-covered oil-can; $\frac{1}{2}$ lb. copper wire.
1 12-inch special hoisting-sheave, for derrick.
1 safety-clamp.
1 set (10) diamond-setter's tools.
100 feet improved drill-rods, in 10-feet lengths, including 2 half-lengths.
1 tool-box, with lock and key.

CHAPTER IV.

POWER DIAMOND DRILLS.

Of these it is proposed to fully describe two types—namely: (1) the Sullivan Machinery Company's drill, and (2) the Bullock Manufacturing Company's drill—which embody the very latest principles of the modern diamond drill, each representing, in its particular type, the most approved combination of mechanical principles for the performance of the work for which it is designed.

A power diamond drill consists essentially of three parts, viz:—

1. The Feed.
2. The Hoisting Apparatus.
3. The Engines.

The Feed.—A definition of a diamond drill feed may thus be stated: that power or force which is applied through a suitable device for the effective passage of the drilling-bit through the rocks which it is desired to penetrate.

The principle of the feed varies in different machines, according to the design of the maker. The varieties consist of:—

1. The Hydraulic, or water-pressure, feed.

2. The Positive, or tooth-geared, feed.
3. The Friction feed.
4. The Weighted, or gravity, feed.

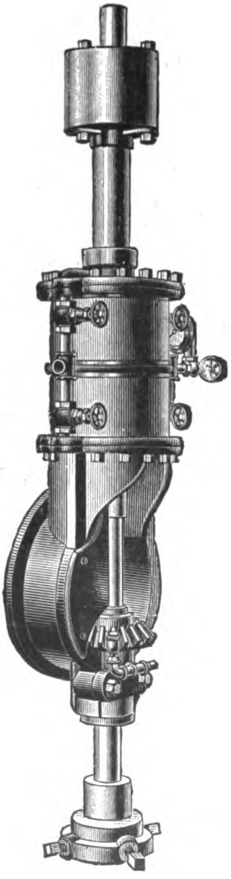

Fig. 11.—Sullivan Hydraulic-feed Cylinder.

The hydraulic feed apparatus consists substantially of a cylinder, within which is a movable piston attached to a piston-rod. Pressure is obtained from a suitable high-pressure steam pump, by an arrangement of water valves, and can at the will of the operator be applied to either side of the piston.

The "Sullivan" Power Drill is furnished with this type of feed, a general view of which is given in Fig. 11, and a detailed sectional illustration in Fig. 12.

In this illustration, A is the hydraulic cylinder in which the piston B moves up and down with its attached piston-rod C. A high-pressure pump is connected to the cylinder at the tee D, the water passing into and escaping from the cylinder through brass tubes F, and ports to which they connect, cast in the cylinder heads. The water valves 1 and 2 are the "inlet valves," and 3 and 4 the "outlet valves."

To the upper end of the piston-rod is screwed a thrust-plate G, through which pass three studs screwed into another thrust-plate H. Between the thrust-plates are two sets of friction ball bearings, one set on each side of a collar I, which is screwed fast to a drive-rod J. The collar I transmits the motion of the hydraulic piston to the drilling-bit, for as the piston and piston-rod descend they carry with them the two thrust-plates G and H and the collar I. The drive-rod J is rotated by a mitre-wheel K through which it slides, the feathers of the mitre-gear sliding in grooves in the drive-rod. The mitre-wheel K is actuated by similar gear on the engine-shaft. The collar I —moving in concert with the piston-rod C — being screwed fast to the drive-rod J, rotates with it, and thus any movement of the piston is communicated to the piston-rod, and from that by means of the collar I to the drive-rod, with the least possible friction. The drive-rod is a hollow tube revolving within the piston-rod; to its lower

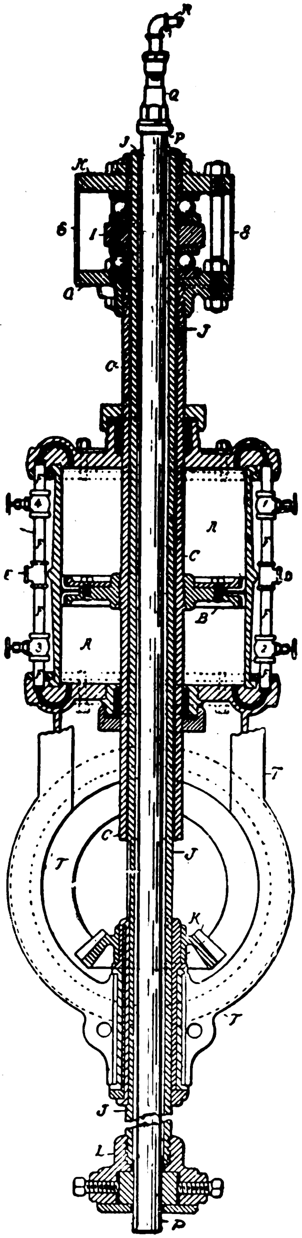

FIG. 12.—SULLIVAN HYDRAULIC-FEED CYLINDER, IN SECTION.

portion, which projects beyond the piston-rod, is screwed a chuck L, which grips the boring-tubes P.

When in operation, water is pumped into the cylinder through the tee D. When the valves 1 and 3 are open, and 2 and 4 are closed, the water pressure is above the piston, and its downward motion is regulated by the manipulation of a valve on the escape tee E. Similarly, if the valves 2 and 4 be open, and 1 and 3 be closed, the water pressure is below the piston, which consequently moves upward, the stroke of the piston being necessarily the continuous effective "feed" of the machine.

The water pressure upon the piston is indicated by a gauge placed between an outer admission valve and the tee D. It has been shown that the motion of the piston is communicated through the piston-rod to the thrust-plates G and H, and again by them through the collar I to the drive-rod J, which finally transmits it to the drill-rods P, through the chuck L. The engine in running, therefore, actuates the drive-rod by means of the mitre-gear before mentioned, and the drive-rod, clamped to drill-rods carrying the diamond-bit is, when boring, forced downwards, whilst rotating, by the hydraulic pressure in the cylinder A.

The positive type of feed is purely mechanical, and consists essentially of an arrangement of differential gearing so proportioned and adjustable that varying rates of feed may be obtained. It is represented in its most perfect form on the Bullock Manufacturing Company's drills, which are described here.

Referring to Figs. 13 and 14, the feed is obtained by varying the relative speeds of rotation of the hollow spindle (or quill) carrying the boring rods, and the bottom spur-wheel N, the boss of which forms a nut

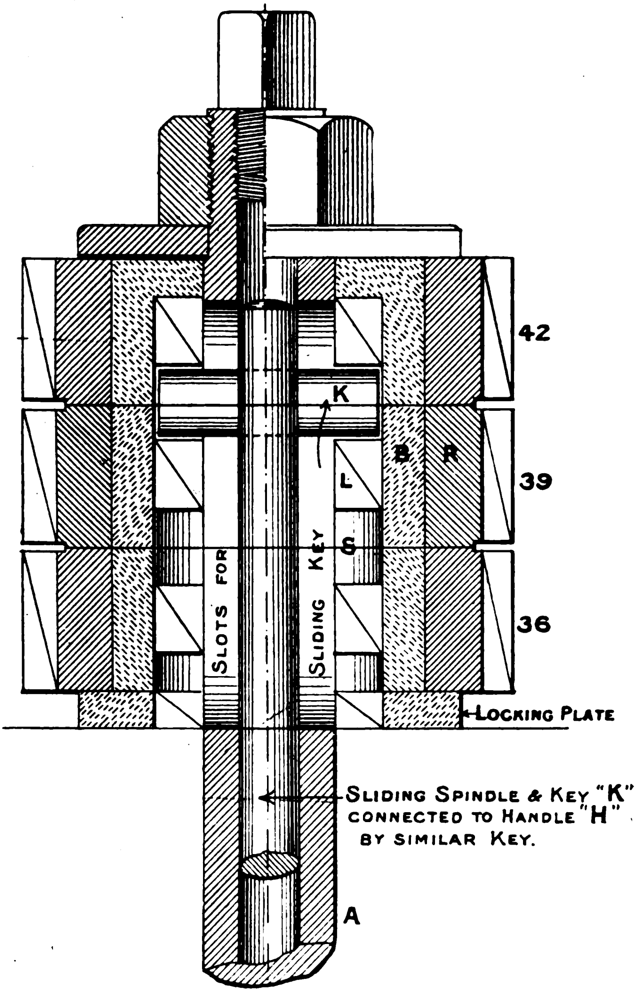

FIG. 13.—BULLOCK'S POSITIVE-FEED.

fitting on the quill, which has a left-hand screw of four threads per inch, as shown.

It is evident that if both screw and nut revolve at

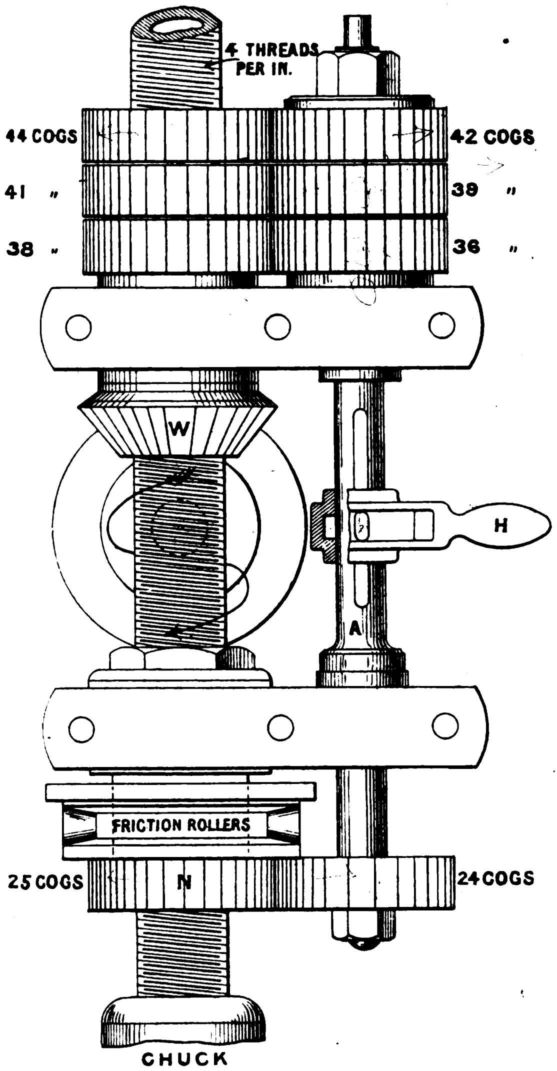

FIG. 14.—BULLOCK'S POSITIVE-FEED.

the same speed there will be no "travel" of the screw, but if the wheel N be revolved more quickly the quill will travel downward, and thus carry down the bore-rods with core tube and crown, the quill being rotated in the direction of the arrow.

The bevel-wheel W is driven by a wheel on the engine shaft. The quill slides freely in W and is rotated by means of two feathers, which fit in keyways, running the whole length of the quill.

The boss of the wheel is prolonged above the bearing, and carries three spur-wheels, which rotate with it· these wheels gear with three other wheels running loose on the spindle A, which is hollow, and has a centre spindle carrying a key K, passing through long slots in the outer spindle, so that it may be raised or lowered, and thus engage with either of the three wheels, which will then cause the spindle to revolve. These wheels have an outer rim of wrought-iron, in which the teeth are cut, and a centre of brass, one portion of which, L, is bored to fit the spindle, but has slots cut in it to receive the key K when required; above and below L is a recess in which the key may remain without contact with either wheel, and beneath the bottom wheel is a fixed plate, with slots similar to those in wheel, and which lock the spindle when the key is lowered with them.

At the lower end of the centre spindle is another similar key passing through long slots in outer spindle, and revolving in a recess in the body of the handle H. This handle can be raised or lowered, and fixed so as to engage the upper key K with either the locking plate or one of the wheels, or to be in the spaces.

Assuming that the key is in the top wheel, the speed of feed will be 1 inch for 700 revolutions of quill, the ratios of speeds of quill and nut N being:—

$$\frac{44 \times 24}{42 \times 25} = \frac{1}{1{\cdot}0057} = 700 \text{ revs. per inch.}$$

$\frac{4}{057}$

With the second wheel in gear the ratio is:—

$$\frac{41 \times 24}{39 \times 25} = \frac{1}{1{\cdot}00923} = 433 \text{ revs. per inch.}$$

With the bottom wheel engaged the ratio is:—

$$\frac{38 \times 24}{36 \times 25} = \frac{1}{1{\cdot}0133} = 300 \text{ revs. per inch.}$$

thus giving three different rates of feeding to suit the varying hardness of the rock.

It may be urged that the positive feed machine may be used in localities where, owing to shortness of water, it would be difficult to run a hydraulic feed machine. My experience is, however, that the quantity of water used in the running of the one, and the other, amounts to practically the same thing, since all the water which is discharged from the hydraulic cylinder escape valves may readily be returned to the pumping sump without appreciable loss.

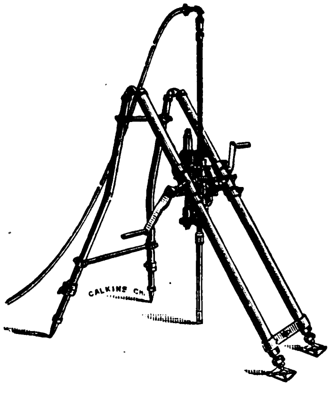

Fig. 15.—Sullivan's Hand Drill.

The friction form of feed is only used in machines of small size, as in Fig. 15, to which the hydraulic feed is not applicable.

It consists substantially of a system of differential gearing, driven by friction instead of positive action. The driving power from the drill-spindle to the counter-shaft is transmitted through leather washers on either side of a loose upper counter-shaft gear. In feeding, the gear and washers are pressed against a collar below them on the counter-shaft, by tightening a compressed spring. This spring is coiled in a sleeve which is keyed to the counter-shaft above the upper gear. When the spring is compressed, the counter-shaft revolves with the upper gear and washers, at a speed determined by the amount of compression on the lower counter-shaft turning the feed-nut gear, and as the amount of compression of the spring, and consequently the friction of the washers, can be increased or diminished at will, it follows that the feed can be varied up to any limit fixed by the proportions of the feed-gear.

The friction feed is supplied to smaller-sized machine drills for two reasons: (1) because it makes a cheaper outfit; and (2) because the principle of hydraulic feed is not easily applicable to machines of a size which require to be light and easily transportable and to be worked by hand power.

The principle of this feed on hand machines is obviously a distinct improvement on either the positive or the gravity feed, because, within the limits of the proportion fixed by the feed-gear, any rate may be obtained by the adjustment of compression upon the coiled spring which regulates the tension.

The weighted or gravity feed consists substantially of a contrivance of a chain and weight, which is fixed in a suitable way to the drill-rods, and by virtue of the force of gravity exercised on the cutting-bit, causes abrasion.

From the above description of the different feeds, the obvious advantages of the hydraulic feed are as follow:—

1. There is no inseparable connection between the steam motor operating the boring crown and the rate of feed of the crown through the rocks. This advantage is very important in drilling through rocks of varying texture and hardness, for although a regular rate of feed occasionally meets the conditions of the rock through which the drill is passing, it is but seldom that such conditions are met with. The hydraulic feed is suited to any condition of hardness, because the rate of feed is not, as in positive machines, a constant and invariable rate of advance, but is, in contradistinction, a feed acted upon by a constant pressure; therefore, given that the drill is passing through a rock having a hardness of 8 (where 10 represents the greatest hardness), and suddenly passes into one of a hardness of 4, the differential rate of progress will be automatically proportioned to the cutting capacities of the diamond bit in a rock of a hardness of 8 to one of 4; that is, the cutting rate will be greater in the latter than the former. With positive feed, on the other hand, the rate of progress through the rock of 8 hardness will remain unaltered in that of 4 hardness, for the reason that the gear in operation at the moment is regulated to an advance of so many threads per 100 revolutions of the machine, the nature of the feed being such that no

automatic adaptation to the rock of lesser hardness can take place, and therefore, with a careless drill attendant, the machine may only be performing 50 per cent. of the cutting that with the automatic device it would be doing.

Conversely, with a hydraulic feed machine, if the rock suddenly changes from a hardness of 4 to that of 8, there is no immediate danger of damaging the crown or twisting the rods, because the principle of the feed is "constant pressure." With positive feed-gear there is danger in both directions indicated, because the mechanical feed, involving the "constant rate of advance" principle, may outrun the cutting capacity of the diamond crown, and hence there is undue pressure upon the stones—causing (1) loss through abrasion, and (2) undue strain upon the hollow boring rods, with twisting, and, may be, stripping of the threaded connections.

The term "constant pressure" used in connection with the hydraulic feed is simply a convenient term expressing the underlying principle of the feed, which only remains *literally* constant at the will of the operator. As a matter of fact, the pressure may be regulated between zero and the highest pressure obtainable from a force-pump by the manipulation of the valve arrangements, which we have previously described.

The importance and desirability of such unlimited feed is obvious in this connection, as the operator is able instantly, and without stopping the engine, to alter the feed to any degree of pressure within the range of the pump and area of the piston. Nor do the advantages cease here, because the feed within the stroke of the hydraulic cylinder piston may be either stationary, forward (that is downward), or upward at will, the engine continuously running. It is evident that, should the rods show a tendency to stick or wedge in the hole whilst the machinery is running, the ability to stop the feed or reverse it without stopping the revolutions of the boring crown will minimise the threatened danger to the vanishing point.

We have, then, clearly established the fact that for general work the hydraulic feed drill covers the greatest field of utility. There may be, and doubtless are, sedimentary formations of such unvarying hardness that the positive feed machine would hold its own against its rival. Granted such to be the case, the fact remains that the hydraulic feed will perform that work equally well, and if required in another position, where the conditions are different, will do the work with greater ease and satisfaction.

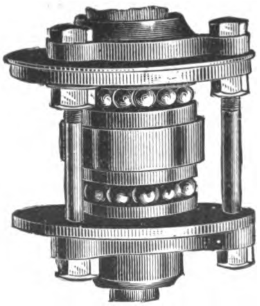

Fig. 15a.—Friction Ball Bearing of Hydraulic-feed Machine.

An important detail of the hydraulic feed machines is the friction ball bearing, Fig. 15a (shown in section also in Fig. 12, p. 31). It consists of two sets of hardened steel balls, ground round and true, which run in grooves in steel plates, which are also hardened and ground. One set sustains the weight of the rods when they hang in the drill-chuck; the other sustains the upward thrust of the rods in drilling. This device reduces the amount of work lost in friction to a minimum, leaving the whole power of the engines for the rotation of the drilling-bit. The friction ball bearing is enclosed in a sheath, which keeps it free from dust and water. By the use of sets of ball bearings it is never necessary to invert the swivel-head, which has to be done with some of the positive feed machines when the weight of the rods becomes excessive.

Another important feature of the hydraulic feed is, that the construction of the hydraulic cylinder and piping is such that the water cannot escape from the bottom of the cylinder faster than it enters at the top; hence the space in the cylinder under the piston is always full of water, and in case a cavity is struck the weight of the drill-rods hanging on the piston is supported by a body of water which, being incompressible, entirely prevents the dropping of the rods. If a cavity is struck, therefore, the hydraulic feed continues downward as regularly as when drilling in hard rock.

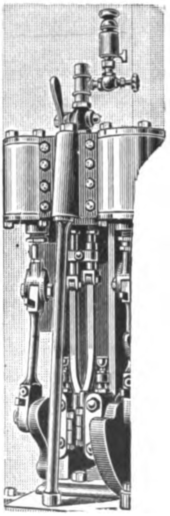
FIG. 16.—ENGINE FOR SULLIVAN DRILL.

Engines, Sullivan Drill.—The Sullivan machines, ranging from 700 ft. upwards in capacity, are fitted with two vertical engines, shown in Fig. 16, set quartering, which may be driven by steam or compressed air. In all surface working the former is adopted and recommended.

The special feature of the engine is the proportioning and adjustment of the valves, which ride upon each other between the cylinders, interact on each other in admitting and cutting off the steam, and are thereby balanced. This secures (1) great compactness in the engines, (2) an unusually quick opening and closing of the cylinder port, and (3) produces a correct distribution of steam for economy and smooth running.

The engines are provided with a relief drip-valve, by which all water can be drained from the steam pipes without entering the steam chest or cylinder, the latter having the usual pet-cock drain fittings. The wearing parts are reduced by the above arrangement to the fewest possible in an engine of the type, and special provision is made for the adjustment of wear and for lubrication, so that the cost of maintenance is practically reduced to lubrication and packing charges, which in engines of this size are very small.

The engines are bolted to a cast-iron base-plate, and have, in the large sizes, an additional angle stay-bolt to secure perfect rigidity.

Engines, Bullock Drill.—The smaller Bullock machines are provided with double engines of the Bullock Standard trunk type, set quartering, and coupled to the main shaft, from which the drill-spindle is driven by a pair of bevel gears. The engines are perfectly balanced, and are capable of running at a high rotative speed without vibration.

The engines of the larger machines are of the double reciprocating crosshead type, 5-inch diameter by 5-inch stroke, provided with Bullock's patent balance-valves, which have extra short ports and consequent small clearance, cutting off at $\frac{3}{4}$ stroke. They are actuated by drag-crank, and are so arranged that they can be moved with a revolving lever.

Sullivan Hoist.—This apparatus in the larger Sullivan machines, shown in Fig. 17, consists of an iron drum, wound with wire rope, which possesses suitable combinations of gearings for hoisting the full weight of the rods from any ordinary depth without having recourse to double blocks. To avoid unnecessary wear, the drum is arranged so that it may be thrown out of gear whilst drilling is proceeding. The drum is fitted with a wood-lined brake — adjustable for wear — operated by a hand lever.

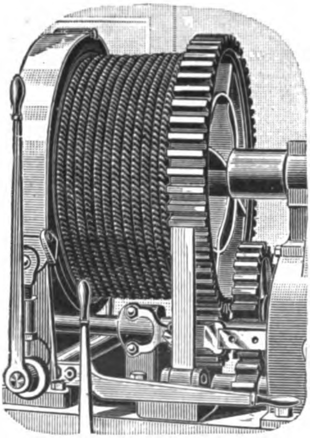

FIG. 17.—SULLIVAN HOIST.

Bullock Hoist.—This, in the machine of the Champion class, is mounted on top of the machine, and consists of an internally-geared friction-driven drum, provided with the necessary levers for operating the friction driver and the hand brake. The proportion of gears on the drum is such that the line of rods, casing, drive pipe, or the drive weight, can be easily handled by a single whip.

On the Dauntless machine the hoisting drum is carried on a steel shaft, running in bronze bearings, and will hold 400 feet of ½-inch or 160 feet of ⅞-inch rope. It is driven by a spur gear and pinion from the engine shaft, and by an arrangement of back gearing four different hoisting speeds and power are attained, with the engines running at 500 revolutions, under 80 lbs. pressure, and developing 26 horse-power.

CHAPTER V.

OPERATION OF MACHINE AND HAND DRILLS.

Commencing Operations.—The first operation of diamond drilling—given that the machine is erected, and all connections made ready for work—is the placing of the "stand" or "drive" pipe, which, together with the drive-shoe, the casing or lining tube, drill-rods, core-shell, core-lifter and drilling-bit, is shown in Fig. 18.

This consists of a length, or lengths, of specially prepared pipe, or, in shallow depths, of ordinary pipe, generally 3 inches or 5 inches in diameter, though in holes where the alluvium is very thick this may be up to 9 inches. Its purpose is twofold: first, to take the returning water and cuttings from the bottom of the borehole, and deliver them into a launder arranged on the floor of the drill-room for their reception, so that the nature of the rock may be seen by the drill operator; and secondly, to prevent the loss of water which would be inevitable in the fissured rocks, or alluvium forming the immediate surface of the ground.

In choosing a site for diamond drilling it is better, other things being equal, to select a spot where there is the least thickness of top soil. In cases where the rock

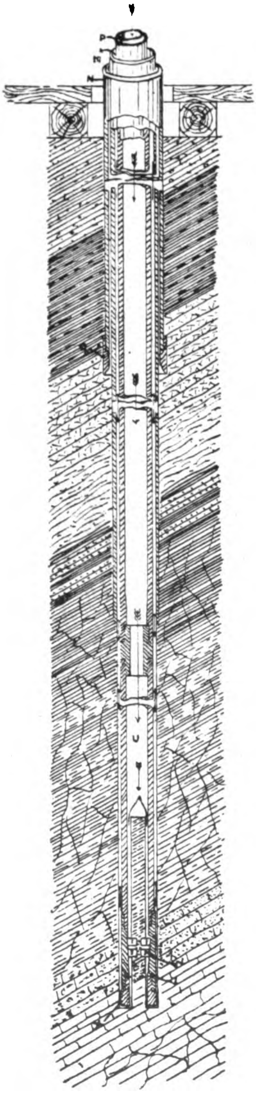

Fig. 18.— A Diamond Drill in Operation.

N—Stand pipe.
M—Lining tube.
P—Boring-rod.
U—Core-barrel.
X—Drive-shoe.
W—Core-breaker.

lies at a maximum depth of 20 feet it is better to sink a hole to the solid rock and place the stand-pipe in a niche cut therein; at a spot previously marked as directly in a vertical line from the centre of the drill-rods.

Should the thickness be such that this method will not apply, then it is necessary to augur a hole with the tools specially provided for this purpose as deep as practicable, large enough to take the stand-pipe, and to force it through, by striking it heavily at the upper end. When this is resorted to, the stand-pipe is fitted with a driving head and shoe.

Should the thickness be such that this method will not apply, then it is necessary to augur a hole as deep as the nature of the alluvium will allow.

If this alluvium consists of clayey material only, it is generally found that the rock can be reached without other aids in this manner; but should it be found that, owing to caving, the hole for the reception of the stand-pipe can only be bored partially into the drift, then to reach the rock from the deepest practicable depth bored other means must be resorted to.*

The stand-pipe must now be forced through the clay to the rock bottom. To do this, the pipe is fitted with the drive-head and shoe before mentioned, the head receiving the blows of a heavy wooden block, which forces the drive shoe and pipe through the drift.

The drive-block is attached to a Manilla rope, which is passed through the sheave at the head of the derrick, and wound two or three turns around the hoisting drum, the loose end being held by a man stationed for that purpose. As the engine runs, the free rope end is alternately loosened and pulled; the result is, that the drive-block is raised to a suitable height by the friction of the turns of rope on the drum, and when the rope is loosened immediately drops and strikes the drive-head. In this way about 40 blows a minute may be struck. A wash-pipe placed inside the drive-pipe follows the shoe downwards; through the wash-pipe a stream of water is forced for the purpose of stirring up the loose material and carrying it to surface in the space between the wash and stand pipes. Pieces of rock, clay, gravel, etc., up to 1½ inches in diameter, can be brought to surface by these means. If large fragments are encountered they must be broken down by use of the chopping-bit (see p. 154).

Casing or Lining Tube.—When the stand-pipe is in

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* If much drift is anticipated, it is better to start with a large pipe, driving it as far as possible, and finishing with one or two smaller. Where several sizes are used, each is subjected to only part of the friction of the loose material in pulling it out, and hence is more easily drawn. The smallest size must, of course, be sufficiently large to admit the casing.

position on the solid rock, the next operation is to make a water-tight joint at its junction with the said rock. To effect this, an inner lining tube or casing is employed. A hole a few feet in depth is first bored into the solid rock with a diamond crown; this hole is enlarged to the proper size by the employment of a casing-bit or reamer. The bit is set in the outside with carbons for the enlargement of the hole. Into the hole so enlarged is lowered a flush-jointed line of tubing, which must project slightly above the stand-pipe at surface. At first a little water and sand find their way into the space between the lining tube and the stand-pipe, but this soon ceases, and the joint is rendered water-tight by the settlement and consolidation of the slimes.

When it is necessary to ream and case below casing already in the hole, either the said casing must be pulled out and the hole continued of the same diameter, or it may be left in and a smaller casing be reamed for, provided, of course, that the smallest casing is large enough for the free passage of the returning water between the drill-rods and casing. The minimum sizes of casing for the various core-barrel numbers are:—

No. of Core-barrel.	Minimum Size of Casing.
A . .	2 inches.
B . .	2½ ,,
E . .	2 ,,
M . .	2 ,,
N . .	3 ,,

The stand-pipe and casing now being in position, the operation of boring may begin.

Lowering the Rods.—Before commencing to lower the rods into the drill-hole, they should be smeared with tallow for preservation and to reduce friction. The machine is then slidden back on its bed, by means of the ratchet and pawl apparatus which is provided for the purpose. The first length of coupled drill-rods—to the bottom of which is attached the diamond crown, core-shell, core-lifter, and core-barrel — has a swivel hoisting-plug screwed into the top end. To the hoisting-plug is attached the lifting-hook, which is fixed to the end of the hoisting-rope. The hoisting-drum is then thrown into gear and rotated by the engine, when the line of drill-rods is suspended centrally over the stand-pipe. A safety-clamp is now brought into position over the hole, the drum thrown out of gear, and the rods lowered from it, the operator controlling the rate of speed by a hand brake. When the top of the rods reaches to within a foot of the floor of the drilling-room the safety-clamp is brought into action and holds the weight securely. The lifting-swivel is now detached and the rope, with the swivel hanging to it, is hoisted by the engine, acting through the hoisting-drum. The swivel is attached to the next line of rods, which are hoisted and lowered in a manner similar to the first lot, the rods, however, in this instance, being lowered on to the top end of the preceding lot and securely screwed in. The safety-clamp is then eased off, and the rods again lowered to within a foot of the floor. This operation is repeated for just as many times as it takes the parted lines of rods to reach near to the bottom of the hole, the repetition being governed by the height of the derrick;

that is, as to whether rods need to be "broken" or parted every 20, 30, or 40 feet.

Having now reached nearly to the bottom of the hole, the machine is slidden forward into its drilling position, and the last rod, which has the water-swivel screwed into its upper end, is passed through the drive-rod of the machine, suspended by a bail and clevis—which grips the rods and a shoulder on the water-swivel — and lowered to make connection with the line of rods already in the hole and held by the safety-clamp. The connection being now complete, the feed is placed, at the commencement of its stroke, in its highest position, and the chuck is screwed fast to the rods. The pump is then started, the safety-clamp is loosened, and the rods are lowered to the bottom of the hole. The bail and clevis is then removed, and the hoisting-drum thrown out of gear, the engine started, and boring begins.

Assuming the unhindered progress of the drilling, the work is proceeded with uninterruptedly for the full stroke of the feed, which varies between 1 and 2 feet. When this has reached its limit of forward movement, the chuck is unloosened, the feed run back to the commencement of its stroke, the rods are again gripped, and so on until the core-barrel is full—that is, until a length of core corresponding to its length has been cut. Core-barrels are usually made 10 feet and 20 feet in length, so that the best run possible without stopping to draw the rods is 20 feet. When the core-barrel is full the machine is stopped, the water-swivel is removed, and the safety-clamp screwed to the rods below the first joint. The chuck screws are then loosened, and the top rod drawn up through the upper end of the drive-rod. The machine being now slidden back on its frame, the drill-runner will have a perfectly clear field for the rod-hoisting.

The swivel lifting-plug is then screwed into the end of the drill-rods, the hoisting-drum thrown into gear, and the rope from the drum is attached through its hook to the lifting-swivel. The rope is made taut from the engine and the safety-clamp loosened; the rods are hauled up and parted into double, treble, or quadruple lengths, according to the height of the derrick employed. On the upward movement of the rods the core-lifter breaks the core off and holds it safely in the barrel.

In this manner the whole of the rods are hoisted to surface. The broken* lengths are stood with their ends on the floor, and are supported against the roof of the drill-shed. They are thus conveniently placed for handling when it is required to lower them again into the drill-hole.

When the last length of rods is hoisted, to which the core-barrel, drilling-bit, etc., are connected, the core-shell is unscrewed from the barrel and the core is carefully extracted and laid in exact order in a box specially constructed for the purpose. Some rocks "core" much better than others, when each are equally free from fractures. On the banket formation of the Transvaal solid cores, the whole length of the core-barrel, are frequently lifted.

At first, and until the hole is at least 50 feet in depth,

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* A line of rods is said to be "broken" when it is parted at any screwed joint.

the drill is run very slowly, in order that the true vertical direction may be maintained as nearly as possible. If the drill is run too fast at the outset, and before the rods have any backing, the tendency is to follow the line of easiest penetration, which may offer in the shape of fractures or joint planes in the rock.

It is necessary also to run slowly at first, in order that a correct judgment may be made of the causes that will interfere with the easy working of the drill later. This is very important, as everything depends upon the correct judgment of the driller. If, for instance, at a depth of 1,000 feet from surface, the drill is showing signs of unusual labour, with only a few inches of core in the core-barrel, the drill runner has to decide upon the cause, whether it is owing to extreme hardness of the rock; whether to an inclination on the part of the drill to go off tangentially to the true direction of the hole; or whether to wedging of the core in the barrel. If he mistakes the cause, the losses involved are (1) the entire crown of carbons; (2) the time required to hoist and lower rods; (3) the time to plug tangential hole and rebore in true direction.

Undue haste to make "footage" at the commencement of a hole may, therefore, result in very serious expense in its later history.

The rotative speed of the drilling-bit should never exceed a maximum of 175 revolutions per minute. If the machine is run faster there is always the liability of grinding the core, owing to rotation in the core-barrel. In heavily-pyritic rocks this is specially the case, because the rock is rendered friable to a greater or less degree, owing to the crystalline character imparted to it by the pyritic grains. As the banket beds of South Africa are pre-eminently of the class of rock whose value is bound up with the incorporation of certain forms of pyrites, the loss of such through attrition might easily mean the condemnation of a fine property, because the core, when extracted, would be found minus a certain length, in which was represented the reef's highest value. The drilling has, therefore, not only failed in the object for which it was started, but has, moreover, possibly branded a valuable section of country as worthless; although, as we elsewhere point out, the results obtained from a single borehole should not be taken as final.

Core-taking.—When a company is running its own drills, the cores, as they are extracted from the barrel, are carefully recorded by the drill superintendent in a book provided for the purpose. The said superintendent must be chosen not only for competency as a diamond setter and drill runner, but also for his honesty and reliability.

When running holes by contract, the property owner appoints a man specially for the purpose of being present each time the rods are lifted, taking the core from the barrel and laying it safely in proper sequence in locked core-boxes. In his record-book he enters all particulars of time of lifting, quantity of core obtained, notes losses, delays, etc. Forms for these particulars are furnished by the company, to whom a weekly report is made of the information contained in the record-book.

Pressure Exerted in Boring.—In working with hydraulic feed machines, in hard formation, the pressure upon the piston in the water cylinder is generally kept at about 80 lbs. per square inch.

Assuming the use of a machine with a cylinder 10 inches in diameter, at the above-named pressure, the total exerted upon the diamond crown is represented by the following:—$10^2 \times 0{\cdot}7854 \times 80 = 6{,}274$ lbs.

In the event of the rods showing signs of jamming, the pump pressure can be raised almost instantly to at least 150 lbs. per square inch, giving an effective pressure immediately applicable to the under-side of the piston of 11,000 lbs.

The range of pressure with the hydraulic feed is alterable at will by the operation of the inlet and outlet valves, elsewhere described.

Method of Setting "Crowns."—The customary method of setting stones in the metal bit is: To bore a hole of diameter slightly larger than that of the stone it is intended to set. A piece of copper foil is then introduced into the hole, as a lining for the diamond, and upon that the stone is laid in such a manner that its strongest and sharpest edges project on the face, and upon the inner and outer side—or both if the stone is large enough—in order that there may be a clearance for the rods, and core-lifter, as well as forward cutting. The stone is then well caulked by hammering a suitable tool upon the soft iron of which the bit is composed. The stone is thus firmly held by the iron bit, and if properly set and used by a skilful man should never loosen unless the crown is used so long that the metal of the bit is worn thin. This latter condition, if allowed to exist, gives rise to serious trouble, not only in the danger of losing carbons, but in the fact that the hole will probably require reaming before a new crown can be introduced; obviously a distinct loss of time and labour.

The stones are so ranged in the circumference of the bit that the cutting and clearing, both inside and out, is taken as upon a solid cutter of given width. The cutting width of the stones is carefully set by calipers before final caulking.

Some drillers prefer to set stones on the outside face of the bit for clearance, but this is unnecessary, unless in a case where the stones are so small that there is no hold for the metal if they are allowed a projection sufficient for the required clearance.

Rate of Progression. — Obviously this is entirely a question of the nature and hardness of the rock which one is boring.

It does not follow, for instance, that because a rock is soft it is therefore easy to make satisfactory progress. A great footage might certainly be made, but the nature of the rocks—as in some clay shales—may cause the development of its stratification planes, through the motion of the boring crown; and the separated portions, because of the rapid rotation of the core-tube, and the consequent grinding action of one piece upon another, would be partially or wholly reduced to a pulverous mass, which is carried to the surface by the returning water, with the result that the driller finds little or no core for his run. In rocks of such a nature, the driller must take every precaution to run the machine slowly and with a low-feed pressure.

Again, the drill may encounter, at a depth of 1,000 feet, a very shattered rock. In these circumstances the careful driller takes the precaution to draw his rods every foot or thereabouts, because, first, of the danger of grinding core and losing it, and secondly, of the certainty of jamming core in the barrel sooner or later.

At a depth of 1,000 feet the raising and lowering of the rods cannot be performed, with Kafir helpers, under two hours, which time is obviously absolutely lost as far sa drilling is concerned. It is, therefore, impossible to fix any definite average rate of progress, excepting through strata whose nature has been absolutely tested. It is further clear that it is erroneous to suppose that because a rock is soft it will be very quickly bored, or that in hard rock the progress will be slower than in soft. In point of fact, a comparatively hard rock, free from fracture, will be more satisfactorily operated upon than a soft rock whose cleavage planes are easily developed, or which has been shattered by earth movements.

The rates of machine diamond drilling progress, for holes up to 1,000 feet in depth, in the following rocks (the rates being intended only as mere approximation), have been deduced from my own experience:—

In basalt, 100 feet per week.
In sandstone (gold formation), 100 feet per week.
In sandstone (coal formation), 150 feet per week.
In slate, from 100 to 150 feet per week.
In chert, 60 feet per week.
In conglomerate, 100 feet per week.

In diabase, 100 feet per week.

In diorite, 100 feet per week.

In South African dolomite (containing cherty bands), 100 feet per week.

In granite, 75 feet per week.

In greenstone, 110 feet per week.

In limestone, from 150 to 200 feet per week.

In porphyry, 90 feet per week.

In quartz, 85 feet per week.

I am, of course, perfectly aware that rates much in excess of these are given in some text-books. I claim for them, however, the certainty of a basis of actual practical performance, and believe that they will be endorsed by every experienced man.

The averages include all normal delays, such as stoppages for repairs, reaming and casing, sticking of rods, recovery of broken core, etc., loose diamonds, losses of water, etc., etc.

CHAPTER VI.

INCIDENTAL OPERATIONS IN DIAMOND DRILLING.

Derrick.—This contrivance is arranged for the expeditious lifting and lowering of the boring-rods. It consists substantially of a frame varying in height from 20 to 50 feet, from the highest point of which is hung a sheave-pulley, over which the rope passes from the hoisting-drum to the hoisting-plug fixed to the drill-rods.

It may be made in tripod shape, or as a braced four-legged frame. For shallow holes, where the machine is likely to require frequent moving, the tripod shape is the best, as it is convenient for dismantling, transference to a new site, and re-erection.

Temporary platforms, at levels suitable for breaking joints in the drill-rods, may be erected on the derrick, these serving also as braces for the frame.

For greater depths a higher derrick is recommended, made of iron tubes, as a bratticed four-legged frame. For depths of 1,000 feet and over these should be 50 feet in height, and should be substantially made. Saving the cast-iron sockets into which the tubes butt, and to which the diagonal stay-bolts are attached, there is no portion of this derrick which is not procurable in any mining camp. The advantages of this type of derrick are that it expedites work when long lengths of rods are being handled, inasmuch as joints need only be broken, when it is in use, every 40 feet instead of every 20 feet with the lower derrick.

The derrick is best erected in sections *in situ.* That is, proceed first to the erection of the lower portion of the derrick, and upon that erect the next portion, and so on.

For a foundation, the writer recommends that the derrick legs be rested upon a 9 by 6 timber frame, to which the drill foundations are connected, as shown in plan and elevation, Fig. 19. This ensures absolute stability to both the derrick and the drill.

On the top of the derrick is placed a wooden frame, bolted at each corner to the derrick. A distance piece of stout pitch pine is placed across this, and bolted to it, from which is suspended a shackle for holding the hook of the sheave-pulley.

Across the horizontal tie-tubes planks are placed, for use as platforms in the manipulation of the drill-rods.

Boilers.—Two classes of these are used:—

1. Vertical boilers, standing on cast-iron base-plate.
2. Locomotive type boilers, mounted on wheels.

The former is only commendable when the country is rough and mountainous. In all cases where it is possible to transport easily the portable boiler is the best.

The usual boiler supplied by drill manufacturers is the water-bottom style, which gives a large water space around the fire, giving free circulation, and is easy to clean. It is provided with a dome, and with fusible plugs in the crown sheet. The smoke-box is formed by continuing the boiler-shell beyond the actual steaming space.

A specification of one of these boilers, for drilling holes ranging from 1,000 to 3,000 feet, is as follows:—

Horse-power	15
Diameter of boiler, in inches	32
Length of furnace	44
Width of furnace	26
Height of furnace	38
Number of tubes	24
Diameter of tubes, in inches	3
Length of tubes, in inches	84
Length of boiler over all, in feet	13
Weight of boiler and fixtures, mounted complete	5,300 lbs.

Each boiler is supplied with all necessary mountings for ordinary work. (Special mountings are required in the Transvaal in accordance with the Boiler Regulations.) The boiler is also fitted with a steam injector, and may be connected for auxiliary feed to the steam pump delivery-pipe. The boiler carriage is strong, with wheels preferably of wrought-iron; a powerful brake is attached for use in controlling the speed of the boiler when travelling down gradients. A hinged funnel is provided, so that it may be laid back in a carrier for safety during transference from point to point.

Pumps.—These are generally of the Duplex pattern, of such well-known makes as Blake & Knowles. For drills of capacities over 1,000 feet the pump recommended has 6-inch steam cylinders, 3-inch water cylinders, and a 7-inch stroke.

Foundations.—When boring deep holes it is essential that the foundations of the machine should be such as to secure absolute rigidity. The dangers of too light a foundation are manifested in the boring operations in—

1. The liability of the machine to shift from its exact original position, resulting in friction on the side of the hole, with consequent undue wear on the rods and increased cost for driving power.
2. The liability of the thrust of the feed moving the machine from its bed, with attendant dangers of jamming or twisting the rods.
3. The danger involved when lifting the rods from great depths.

In order, therefore, to secure perfect rigidity and the best operation of the plant, it is recommended that the machine foundations be of the same length as the outside frame upon which the derrick rests (see Fig. 19), gaining in this manner the entire weight of the machine and derrick as against the pull exerted in lifting the rods and the upward thrust from the boring bit.

After levelling up the foundation timbers, the machine —standing upon its own wooden frame—is securely bolted to them. The derrick is now erected, and the boiler hauled into position. The connections of boiler pump, drill, etc., are shown in Fig 20.

Core-boxes.—These are made of wood, of sizes, and in the manner shown in Figs. 21, 22, 23.

Jamming of Rods.—The jamming of rods may be due to any of the following causes :—

1. Caving of the hole.
2. Mud rush into the hole.
3. Working with a worn bit.
4. Too little space between the rods and casing.

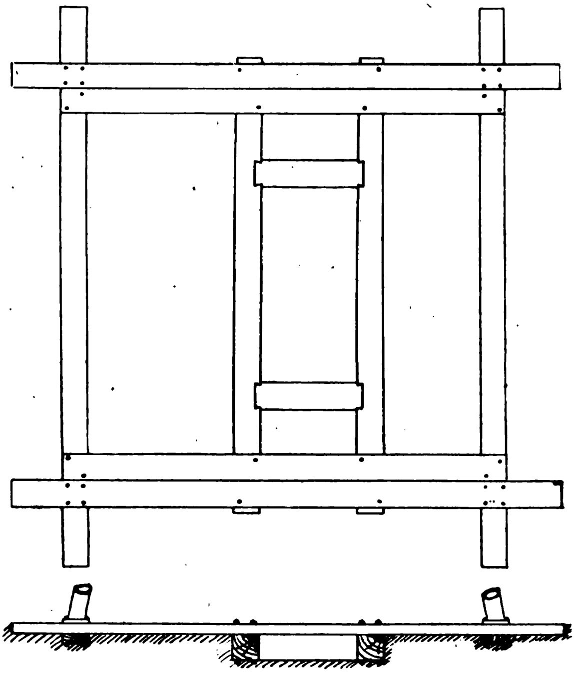

FIG. 19.—DERRICK FOUNDATION IN PLAN AND ELEVATION.

1. *Caving of the hole.*—It seldom happens that any trouble is experienced from caving, when the drill is running, because any falling-in particles are kept in

motion by the upward water current engendered by the pump between the sides of the hole and the drill-rods, and therefore settlement is extremely improbable.

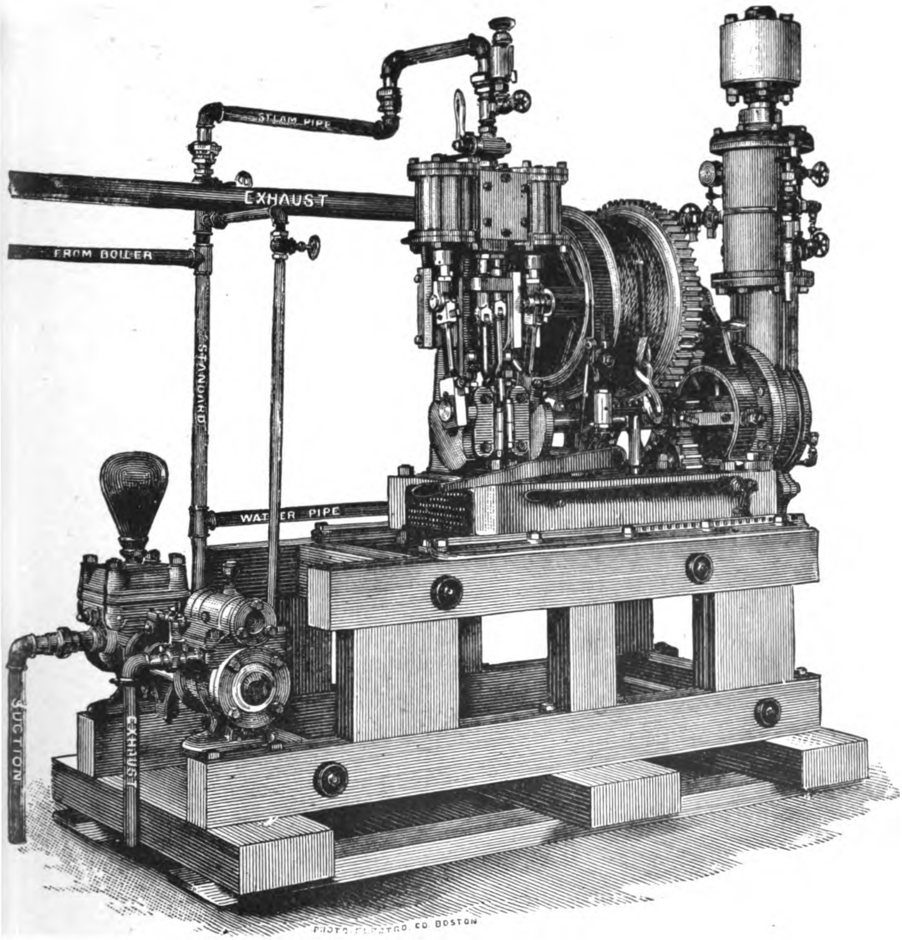

Fig. 20.—Boiler Pump, Drill, etc., in position.

Jamming of rods, through caving, occurs much more frequently because of carelessness of the drill runner than from any other cause, and invariably occurs in the upper sections of the hole—that is, in those portions which are either drifty or clayey. These sections demand, as we have elsewhere seen, the precaution of using stand-pipe and casing, for their support. In order to make footage, drillmen will risk the chance of caving rather than lose the time involved in driving stand-pipe and reaming for casing. The risk is apparently justified in some instances by the completion of the hole without any sign of caving, but a time comes when all the time and cost saved in running holes without fully reaming and casing are absorbed in the recovery of, maybe, hundreds of feet of drill-rods, with all their drilling appurtenances, which have been jammed fast in a hole.

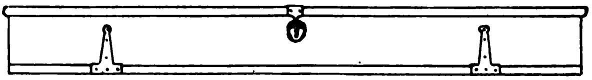

Fig. 21.

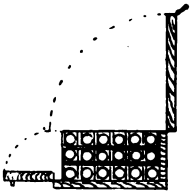

Fig. 22.

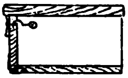

Fig. 23.

Core-Boxes.

The machine will usually give some warning to the drill runner before sticking, and in case he is running a hydraulic feed machine he, without stopping the engines, reverses the direction of the feed, pumps more water into the hole, and possibly, by the upward and downward movement, with rotation, which the hydraulic feed allows, will avert the threatened danger. With the positive feed machine he stops the feed, keeping the engine rotating, in the meanwhile increasing the pumping pressure. Should these means prove futile to prevent sticking, the question that is before him is the recovery of the rods, dealt with in another place.

2. *Mud rush into the hole.*—This may happen at any depth in a borehole, but, similarly to the last case, will seldom cause sticking if the drill runner is careful. Whilst the engine is running, and the pump working, the incoming mud will be carried off by the upward current of water, so that there is no danger at that stage. The danger lies in the practice of many drill men, who assume that the bottom of the hole is always clear, and that they may lower the rods to the bottom with impunity. In the case assumed, the mud which was easily dealt with, and removed whilst the drill was running, will be gradually filling the lower portion of the hole when the rods are lifted, and hence, when the rods are lowered, they enter a mass of mud, which, owing to the weight of the rods, is forced up, both inside and outside of them: the consequence being that, when all connections are made, and the machine is ready to run, the rods are held firmly in the binding grip of the mud, and the question again resolves itself into the recovery of the rods.

The whole trouble, delay, and expense which is incurred in the jamming of rods, under these conditions, would have been avoided by a little care and foresight on the part of the drill runner. Instead of lowering the rods to the bottom, and then making the pump connection, this should be made before the last length of rods is lowered—that is, whilst the crown is still anywhere from 10 to 40 feet from the bottom of the hole. The pump should then be started, and the rods slowly lowered, and the presence of any impediment will not only be made known by the colour of the returning water, but the impediment itself will be removed by the rotation and forward feed of the rods, in the usual way.

3. *Working with a worn bit.*—This cause of jammed rods is on the face of it due to inexcusable carelessness. If no metal bits are procurable on the instant, the drill runner is forced either to use a worn bit or to suspend work. It is far better to take the latter course, and to wait their arrival, than to risk what is sooner or later inevitable. Not only are the rods liable to stick fast, because the crown is boring a hole that is too small to admit free passage of them, but a secondary cause—which is tantamount to the mud rush—is created, because the space between the rods and the hole is not sufficient to allow of the passage of the gritty and slimy particles cut by the drilling-bit, and hence, if any stoppage occurs, these silt round the drill-rods and hold them fast. Or supposing that there is not "bind" enough to hold the rods, owing to the motion imparted by the upward current, there is still the danger—and the writer has quite recently seen two instances of it—of lowering the rods into the slimy borings which have remained in the hole after the rods have been lifted, which slimes may be—and in the instances referred to positively were—capable of causing all the trouble and loss involved under this heading.

A careful and conscientious diamond setter will, of course, see to it that the crowns employed are well up to the gauge, for he recognises, that not only is the sticking of the rods a possibility, but also that the hole will assuredly have to be reamed as soon as a new crown is introduced—which process means, in these circumstances, unnecessary wear on carbons, delay, and loss generally.

4. *Too little space between the rods and casing.*—In the foregoing discussion the dangers of too little space for the upward passage of the drill-borings are fully shown; therefore it is unnecessary to repeat them under this head.

Recovery of Jammed Rods.—The methods of recovering jammed rods vary with the assumed position of the "bind." If this occurs in the superficial clay or drift sections, one method is to free the rods by sinking a hole for the purpose. Another is to set some carbons in a piece of metal of sufficient diameter to encompass the first stand-pipe, affixing the improvised crown to an ordinary drive-pipe of the same diameter, and using this combination to bore down beyond the point where the rods are sticking. The rods may then easily be drawn.

In case, however, the point of "bind" is at some depth, power must be applied from the engines, through the hoist. Should this fail, powerful differential blocks may be rigged over the hole and tried. These will either draw the rods, or strip the joints at the point of "bind." A recovering tap is then used, and power again applied. All other sources failing, the rods must be chopped out by steel tools, or the hole, with its valuable contents of carbons, etc., and with its accomplished footage, abandoned.

The recovery of rods, which requires the power of powerful blocks to move, is, in any case, absolutely destructive to the rods. The torsion is so great that they sometimes elongate as much as 6 inches on 10 feet, the thread is entirely or partially stripped, and generally the rods are good for nothing but the scrap heap.

It is, therefore, the duty of every diamond driller to take all possible precautions to prevent the rods sticking, otherwise he courts what may prove a calamity to his employers.

Loss of Water in Borehole.—This is probably the most frequently occurring hindrance to regular progress in diamond-drilling operations. In localities where water is scarce or distant the loss of a certain quantity of water, which was calculated upon for re-use, is itself a direct extra charge on the borehole, and, in addition, the supply may be so limited that any serious loss means that the machine cannot be run full time. More serious still, however, is the aspect when taken in connection with the drilling indications.

In all machines, of any make whatsoever, it is of primary importance that the drill runner should have some tangible evidence of the nature of the rock through which he is passing. It is patent that he may take the most perfect note of the "thrust," the rate of cutting, etc., but from such indications only can he gather (1) the hardness of rocks, that is, as to their range between 1 and 10; (2) the probability that, since there is no "thrust," the drill is either passing through an open fissure or a clay seam.

These indications, though absolutely essential for successful performance, do not fulfil the complete functions of drilling indications, because they do not present to the drill runner any ocular proof of the rocks which he is boring. If, for instance, a drill is testing a section for coal, and the coal formation is intercalated with sheets of igneous rocks: Assume that the upper layers of these have been decomposed, their hardness may easily be mistaken for that of coal, which is about 2. Again, assume that the coal is at length reached, the drill runner has no indication from his "thrust" that it is anything but another rock of a hardness of 2; he possibly runs through the seam, and when at length he draws the core discovers that he has passed through the coal, and has probably lost a considerable proportion of it.

In order, therefore, to supplement the evidences which the "thrust" affords, it is necessary to see the nature of the rock itself. This is attained by bringing the abrasions continuously made by the cutting-bit to the surface, by means of the water which is pumped down the hollow drill-rods. The colour of the returning water, taken together with the hardness as shown by the "thrust," is the first important indication, from which may be concluded a very great deal. In addition, also, the driller may lead the water and cuttings into a settling-tub, and can then handle particles of the rock which is at the moment under process of boring.

The loss of water under this aspect, therefore, proclaims it to be one quite inimical to the satisfactory issue of the borehole, and hence it must be combated somehow. To do this, one of three courses is open:—

1. The leakage must be stopped either by passing in material, which will fill it, or by reaming and casing the whole depth of the hole to some depth beyond the fissure.
2. Enough water to make up the leakage must be supplied, whilst yet returning sufficient to the surface to give the required indications.
3. The hole must be abandoned.

The first course is naturally the one that is at once resolved upon.

If the leakage is not great, a common practice is to pump Indian corn meal (mealie meal) or bran into the hole. These materials find their way into the fissure, and by their faculty of expansion will frequently close it.

If the leakage is so great that no water is returned to surface, then cement is employed. It is pumped down in quantity, and allowed time to set. In almost every instance in which the writer has seen this method employed it has proved successful.

Here is a case. In a borehole which was located on the black reef, a fissure containing mud and stone drift was struck at a depth of 500 feet. From the one wall to the other, in a vertical direction, that is, in the line of the borehole, the distance was 4 feet. The angle of inclination of the fissure was about 65 degrees. The drill was run through the drift, the pump meanwhile running under great pressure to make a clear space for the introduction of cement. When the bit encountered the lower face of the fissure it would not "bite," owing to the high inclination of the wall and to its hardness. It was then seen that it would be necessary to clear out a very large space in order to get a body of cement in the hole, for steadying the bit upon its encounter with the fissure wall. After making certain that a very large cavity was clear, about 1½ casks of cement were passed into the hole, which was then allowed to stand for some days.

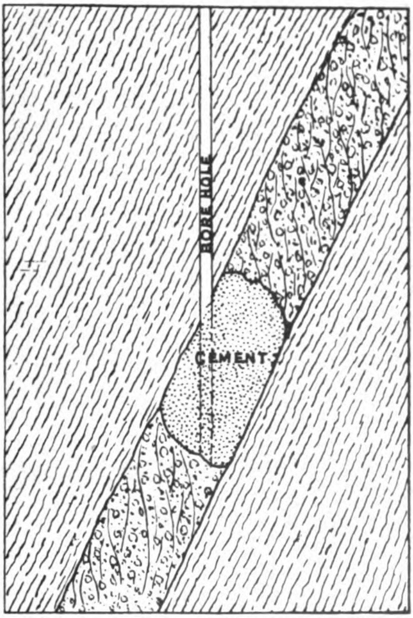

Fig. 24.—Illustrating Fissure encountered in Rock and filled with Cement.

The diagram given in Fig. 24 reflects the conditions just described. Upon the re-commencement of work, the drill passed successfully through the cement and into the lower wall of the fissure, and no further trouble or loss of water was experienced.

Another case, which occurred in a hole located by the writer on a banket series, in which every means tried for the stoppage of the loss of water proved unsuccessful, was as follows: At a depth of 647 feet the water was suddenly lost; time after time cement was passed into the hole and allowed to set, but in every instance the re-starting of the pump proved that the fissure was still open. The cause of the failure of the cement to stop the leak was probably due to a running stream of water in the fissure, which simply carried off any filling material as fast as it was placed in it.

A certain quantity of water only was available in the vicinity, and in order to have volume enough to return some to surface, despite the leakage, it was necessary to discontinue night-work and run only the one shift. By these means we were enabled to finish the hole to the required depth, but naturally the cost was considerably greater than when running the machine full time under good conditions.

In soft formation, even at the depth mentioned, the proper course would be to ream and case the hole below the fissure. In hard banket formation, however, when there is no danger of the pump pressure destroying the core, it is simpler to supply the extra water if the drill has already nearly reached its required depth.

If a hole is set for 2,000 feet in depth, and a fissure at the depth above mentioned was struck, there would be no alternative but to stop drilling, and ream and case the whole depth.*

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* The record of the Bezuidenville borehole, situated near Johannesburg, some details of which were supplied in a paper to the Institute of Mining and Metallurgy, London, by Mr. J. A. Chalmers, shows that in a total depth of 3,728 feet only 88 feet of casing were required.

Percentage Loss of Core.—The percentage of core obtained from drill-holes varies with the length of the rods. In the superficial zones—that is, where these are occupied by clay or drift or fragmental rocks—the core recovered may be anywhere from nil to 50 per cent.

Once, however, the solid formation is struck, the average core, as against depth drilled, should be not less than from 95 to 98 per cent. in banket formation. Higher averages than these can be made by extraordinary precautions—*e.g.*, running slowly, lifting rods frequently, etc.—but the rate of drilling, when the machine has reached a depth of 3,000 feet, would be so slow that practical economy forbids the cost involved in maximum efficiency, and therefore the figures named will be found to fairly represent average performance.

The following figures show average losses recorded by the writer:—

Shale, 5 to 7 per cent.
Diabase, 1 to 2 per cent.
Quartzite, 3 to 5 per cent.
Schists, 8 to 10 per cent.
Limestones, compact, with chert, 2 to 4 per cent.

Recovery of Lost Carbons.—Despite the most careful running and greatest pains taken in setting carbons, it happens in every diamond driller's experience that stones are torn out of the crown; or that, through an accident, the rods drop to the bottom of the hole, damaging some or all of the stones. Such a loss may occur to an inattentive drill runner, through too great pressure upon the drilling-bit in hard and fractured rocks; or through the dropping out of one stone, upon which the remainder may grind themselves out.

Any experienced drill runner can immediately tell from the sound of his boring-rods, when running, if anything unusual is happening in the hole, and his practised ear will inform him whether he should hoist the rods or not. The loss of an entire crown, barring unavoidable accident, is, therefore, due to inexperience or incompetence, and hence is, in most instances, a preventable matter.

Lost diamonds are recovered by fitting a ring of beeswax or clay on to the end of the drill-rods, and lowering them to the bottom of the hole. The diamond is pressed into the soft medium employed, and raised to the surface in the usual manner. This method, intelligently applied, never fails to recover the lost stones, if such are really recoverable. A diamond is sometimes known to be in the hole, and every available means fails to discover its whereabouts. In such cases, if not ground up, the assumption is that it has been forced into a fissure in the rock, and cannot be dislodged by any means at command. A shell pump may also be used for this purpose.*

Size of Borehole.—The boreholes are usually somewhat larger in diameter at the commencement than in their deeper sections. The reason of this is to allow some play for the rods, to allow free passage for the upward current

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* A shell pump is a tube of iron, or even of tinned plate, with a valve opening upwards in the extreme lower end. The shell is lowered to the bottom of the hole and rapidly worked up and down for some minutes. Loose pieces and debris are carried into it by the rush of water and are deposited above the valve, and carbons if loose may thus be picked up.

of water and borings, and to provide a hole of such diameter that, if casing is necessary, reaming will be more quickly performed.

The following table gives the usual sizes of boreholes and cores proportionate to depth :—

Depth of Hole.		Diameter of Crown.	
		Outside diameter.	Core diameter.
		Inches.	Inches.
Up to 500 feet	To 200 feet	$1\frac{7}{8}$	$1\frac{3}{16}$
	200 to 500 feet	$1\frac{3}{4}$	
Up to 1,000 feet	To 500 feet	$2\frac{3}{32}$	$1\frac{3}{16}$
	500 to 1,000 feet	$2\frac{1}{16}$	
Up to 1,500 feet	To 1,000 feet	$2\frac{3}{32}$	$1\frac{3}{8}$
	1,000 to 1,500 feet	$2\frac{1}{16}$	
Up to 2,000 feet	To 1,000 feet	$2\frac{1}{8}$	$1\frac{3}{8}$ to $1\frac{1}{2}$
	1,000 to 2,000 feet	$2\frac{3}{32}$	
Up to 2,500 feet	To 1,500 feet	$2\frac{1}{4}$	$1\frac{1}{2}$ to $1\frac{5}{8}$
	1,500 to 2,500 feet	$2\frac{3}{32}$	
Up to 3,000 feet and over	To 2,000 feet	$2\frac{3}{4}$	$1\frac{1}{2}$ to 2
	Balance	2	

CHAPTER VII.

DEFLECTION IN BOREHOLES.

It sometimes happens in diamond drilling that the true direction of a hole becomes deflected so seriously that the cores obtained from the hole are entirely misleading.

In this connection I cannot do better than give a quotation from Mr. Bennett H. Brough's "Treatise on Mine-Surveying"* (sixth edition, page 307), where, under the head of "Use of the Magnetic Needle in Surveying Boreholes," he says:—

"It has been assumed that the diamond drill always bores a perfectly straight hole, even though passing through rocks of different hardness. Actual experience reveals an entirely different state of things, the deviations sometimes being so great as to render a borehole misleading. An ingenious plan of correctly ascertaining these deviations has been devised by Mr. E. F. Macgeorge, an Australian engineer. His plan consists in lowering into the borehole clear glass phials filled with hot solution of gelatine, each containing, in suspension, a magnetic needle, free to assume the meridian direction. The phials are encased in a brass protecting tube,

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* London: Charles Griffin & Co., Limited.

and let down to the depth required, being allowed to remain for several hours until the gelatine has set.

"The construction of the phials or clinostats can be seen from Fig. 25. The clinostat is a true cylinder of glass, made to fit accurately within the brass guide-tube. At the lower end it terminates in a short neck and bulb, within which a magnetic needle is so held by a glass float as to stand upright upon its pivot in every position of the phial, and thus allow the needle to assume the meridian freely without touching the sides of the bulb. Passed through an air-tight cork and screw capsule at the upper end is a small glass tube, terminating in another bulb above, and with its open lower end inserted in a cork which enters the lower neck of the phial, thus preventing the escape of the needle and float in the lower bulb. The upper bulb contains a very delicate plumb-rod of glass, consisting of a fine rod terminating in a plumb of glass below, and a diminutive bulbous float of hollow glass above. It is carefully adjusted to the specific gravity of the gelatine in which it is immersed, so as to insure the rod being truly vertical, whatever the position of the phial and bulb may be. When the gelatine is fluid, the plummet hangs freely perpendicular, whilst the needle in the lower bulb assumes the magnetic meridian. When, however, the phial is at rest in any position the contents solidify on cooling, and thus hold fast the indicating plummet and magnet in solid transparent material. On withdrawal from the borehole the phials can each be replaced at the same angle at which they cooled,

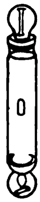

FIG. 25.
CLINOSTAT.

and when the phial is revolved upon the part where the magnetic needle is seen embedded in the gelatine, until the needle is again in the meridian, the phial is manifestly in the same direction, both as regards inclination and azimuth, as it was when its contents were congealed, and thus the gradient and bearings of the borehole can be determined. By repeating the observations at intervals of every 100 feet the path of the borehole can be accurately mapped.

"This method was first applied at the Scotchman's United Mine at Stawell, in Victoria, and was so effectual as to enable the borehole to be found 37 feet away from its supposed position, at a depth of 370 feet, a deflection that increased to the large amount of 75 feet at a depth of 500 feet. An exploratory level failed to find the borehole at its theoretical position, assuming the drill to have gone straight down. The subsequent search works lasted for more than a year, and cost, altogether, £3,663. Had the method been available at the commencement, the level driven would have cost only £1,352, and the saving effected would have been no less than £2,311.

"By means of the clinograph, as the inventor terms his apparatus, a bore may be straightened when so deflected as to endanger the safety of the drill; for suppose a borehole to have deflected suddenly, the depth of the point where the most serious deflection took place can be found. Then, if an indiarubber washer is forced down to 20 feet below this point, and liquid cement run in until it reaches some feet above the point of deflection, and allowed to set, then the drill may be again lowered and started gently, until it has started fairly in its corrected path, when the usual speed of boring may be resumed.

"A less satisfactory method for ascertaining the inclination and direction of boreholes was suggested by G. Nolten. In the instrument employed the amount of deviation is etched upon glass by hydrofluoric acid; whilst the direction is found by means of a compass needle, clamped by the aid of a stop-watch, after sufficient time has been allowed for settling. Notwithstanding the great imperfections of this instrument, its use in Germany has revealed some startling deviations of boreholes. In a borehole at Dienslaken, bored with a rotating drill, the deflection amounted to 47 degrees at a depth of 750 feet. The borehole undertaken by the German Government at Lieth, in Holstein, was but little better than the preceding; but by a lucky accident the deflection of 3 degrees at 984 feet gradually changed to the opposite quarter of the compass at 1,640 and 2,624 feet, and concluded with a deflection of only 1 degree at 3,280 feet."

I also extract the following account of a method of surveying boreholes, by Mr. Andrew F. Cross, from the report of a meeting of the South African Association of Engineers and Architects, held July 28th, 1897:—

"The apparatus consists of a multiplying winch, on which is wound 4,200 feet of highly-tempered steel wire—Birmingham gauge No. 19, with a breaking strain of over 450 lbs. This wire passes over a drum, having a circumference so that one coil of wire is exactly equal to one foot in length, and, as the wire is paid out, every revolution of the drum is indicated on the dial, so that the exact depth of the weight at the end of the wire is accurately shown. The end of the wire is provided with a loop, very carefully made, in order to stand as great a strain as the wire itself. This loop is fastened by a swivel arrangement to a 2-foot long brass tube. The object which I have in view is to determine the exact position of this brass tube at any given point. By 'position' I mean the number of degrees it deviates from the vertical and the direction of this deviation as regards the magnetic north.

"First of all I have a small brass tube, which fits accurately into the large tube. The small tube (which I will call B, the large one being A) has a steel needle fitted inside the base. On this needle a little aluminium thimble is balanced. On the top of this thimble is a tiny circular mirror, so adjusted that, when the tube A, containing B, hangs vertically, the surface of the mirror is exactly on a horizontal plane.

"I have also another brass tube (which I shall call C) likewise fitted with a needle; on this needle a little magnet swings—the north pole being marked. This little magnet has two aluminium pins near each end, pointing downwards. Each of the little brass tubes B and C can be hermetically closed with a brass cap provided with a leaden washer. They are likewise grooved longitudinally at a certain point, and fit into the tube A. Tube A, which encloses the smaller tubes B and C, can also be hermetically closed by caps at each end provided with leaden washers.

"First I shall describe the operation of measuring the deviation from the vertical. I take a certain liquid, which has the peculiar property of retaining its liquid form for one hour at any ordinary temperature. I partly fill tube B with this liquid, and at whatever angle (within certain limits) the tube is held the mirror will still be in a horizontal plane. After the liquid has solidified the mirror will retain the position in which the solidification took place. It is very easy by optical means to measure the angle so obtained, very much in the same way as in the well-known goniometer. This method of measurement is very much more accurate than any mechanical appliance that could be adapted to so small a space, as the diameter of our usual boreholes does not permit of the use of a larger tube. Tube C, containing the magnet, is also partly filled with the same liquid, so that, when the mirror in tube B becomes fixed, the magnet in C is likewise fixed.

"The method which I use to measure the direction of the deviation is as follows: First I measure the angle of deviation from the vertical; then I take this specially-constructed apparatus, which is placed, as you will observe, pointing to the magnetic north. I then hang tube A in a marine compass swivel, which allows the tube to swing freely in every direction without turning on its axis. I now put in tube C, containing the magnet, which is fixed by the solidifying of the liquid. I loosen one of the thumb-screws, supporting tube A, and turn the tube on its axis until the magnetic needle is exactly parallel with a line passing through the centre of the apparatus. This line shows the magnetic north and south. I must not forget to mention that the apparatus must be placed on a true level by adjustment of thumb-screws and using a spirit level in the usual way, so that the large tube A hangs exactly vertical when free. On the lower part of the apparatus is a circular board revolving on a screw; the centre of this board exactly coincides with a line passing longitudinally through the centre of tube A. Tube B, containing the mirror, must be placed in tube A. Tube C, containing the magnet, must be withdrawn. Tube B will take the exact position it originally occupied, as a groove in the side fits into a feather in tube A.

"I now place tube A exactly in the angle, formed by observing the deviation from the vertical, as shown by taking the observation from the mirror. Having done this, an assistant slowly revolves the circular board until a reflection of cross wires, placed exactly perpendicularly above the mirror, is reflected back on these cross wires. When this occurs, I know that the tube A is exactly in the position which it had when the magnet and the mirror became solidified in the borehole, at the point whose depth was indicated by the dial.

"All that I have to do now is to read off the number of degrees which the pointer, supporting tube A, deviates from the magnetic north. By this means I have determined, first of all, the deviation of the borehole from the perpendicular, and, secondly, the direction of the same. The advantages of this apparatus are, that when once the liquid used has become solid, there is no possibility of an accidental jerk altering either the position of the magnet or of the mirror. The optical method of measuring angles ensures great accuracy, and the whole arrangement can be adapted to holes of very small diameter."

The danger of serious deflection in the borehole is considerably greater when boring in strata that nearly approach the vertical than in strata having a dip between 30 and 50 degrees. Consequently, the driller upon the banket areas of the Transvaal has so much in his favour, and it is seldom that he is confronted with this difficulty. In one hole bored under our supervision we were led to believe that the bit had deflected, and testing verified the belief. By simply filling the deflected portion with cement, and allowing the latter three days to set, we were able to bring the hole into true line.

Watchfulness and good judgment on the part of the drill runner will detect any inclination of the bit to deflect, and the precaution of using cement early in the deflection stage will obviate much useless expense in boring, wear and tear on rods, and possible unsatisfactory issues.

CHAPTER VIII.

COST OF DIAMOND DRILLING.

THE factors that enter into the costs of diamond drilling are very variable, according to locality. Primarily they may be stated as (1) Labour; (2) Water; (3) Fuel; (4) Carbons.

Labour.—In countries where diamond drilling is recognised as a feature of prospecting work there is no difficulty in obtaining competent and reliable drill-runners. In places where, on the contrary, it has not been generally resorted to, there will always be some difficulty in procuring them. It is, however, certain that, with the advancement made by the diamond drill within recent years, the conditions which call for prospecting by its means will be met by its general application, and in turn, as demand for this special class of labour is created, so will the supply be forthcoming.

In South Africa the staff for a machine diamond drill is usually as under:—

Superintendent,	White men.
2 Drill-runners,	
2 Stokers,	Kafirs.
2 Derrick hands,	

The superintendent is responsible for the core and the general drilling costs. He sets all the bits, and maintains the general supervision and discipline.

The drill-runners are the men engaged in the actual running of the machine. They erect or dismantle the outfit, make repairs, superintend the Kafirs, and are responsible to the superintendent for the machine's effective performance.

The firemen attend to the keeping of the working steam pressure and to the boiler generally. During the time of hoisting, or lowering rods, they stand on the floor of the machine-shed and break or couple the rods below the drill-chuck, whilst the drill-runner is operating the engine or hoist-break.

The derrick hands stand on the derrick platforms, unscrew the hoisting-plug and lower it each time the rods are broken in raising, and affix the plug into the end of the uncoupled sections when they are lowering.

Wages paid to drillmen:—

Superintendent, £40 per month.

Drill-runners, £26 per month.

Kafirs (including food), from 65s. to 70s. per month.

Ten hours are worked on each shift, and 12 shifts a week are run.

MONTHLY COSTS OF RUNNING DIAMOND DRILL ON HOLES UP TO 1,000 FEET IN DEPTH.

Fuel is assumed to be £1 per ton.

Carbons are assumed to be £7 10s. per carat.

Water is assumed to be sufficiently near the drill to be delivered to the pump sump by hand.

Assumed monthly cutting, 400 feet.

Then:—

	£	s.	d.
White wages — Diamond setter, per month	40	0	0
Two drill-runners, at £26	52	0	0
Fuel, 25 tons	25	0	0
Kafirs (1 stoker, 1 derrick hand, on each shift = 4 at £3 per month)	12	0	0
Pumping—2 Kafirs, one on each shift, at £3 per month	6	0	0
Carbons, 1 carat to 15 feet, say	200	0	0
Bits, at 1d. per foot, say	2	0	0
Oil and repairs	5	0	0
Depreciation, say 10 per cent. per annum on £1,755 = for one month	14	12	6
Total monthly cost	£356	12	6
Cost per foot	0	17	10

Cost of Reaming and Casing.—The cost of reaming is, of course, dependent on the diameter of the hole. If, for instance, the hole is 2 inches in diameter, and it is required to ream to 2½ inches, the amount of surface that the diamonds will have to abrade is considerably less than the reaming of a 2½-inch hole to 3 inches in diameter. As a rule, reaming will proceed at twice the average rate of boring. If we take this latter to be 25 feet per diem, then reaming may be taken at 50 feet per diem, or 1,200 feet per month.

The cost of reaming (assuming the average footage to be correct) is as under:—

	£	s.	d.
White wages	92	0	0
Native ,,	18	0	0
Fuel	25	0	0
Carbons, say	300	0	0
Bits	5	0	0
Oil and repairs	5	0	0
Depreciation on plant, say 10 per cent. per annum on £1,755 = for one month	14	12	6
Total	£459	12	6

	£	s.	d.
Thus the total cost of reaming 1,200 feet	459	12	6
Cost per foot equals	0	7	8
Cost of 100 feet of 2-inch casing, say	22	10	0
Cost per foot	0	4	6
Total cost of reaming and casing per foot	0	12	2

Carbons.—On account of the superior hardness of the diamond, it is employed very extensively in the operation of rock boring. Any of its numerous varieties, provided they are free from flaws, or easily-developed crystallisation planes, may be used; but the stones preferred by drillers are the black carbonados of Brazil, which combine with exceeding hardness the amorphous structure which is rarely attained in the ordinary white stone.

Owing to the comparative rarity and cost of the black diamond, imitations of it, as found in its native state, are often encountered by the diamond driller.

The substituted mineral is corundum, which has a hardness of 9 and a specific gravity of 4, as against hardness 10 and a specific gravity 3·5 in the diamond. In its natural state the corundum is sometimes colourless, but more usually red, blue, yellow, or brown, with seldom any distinct cleavage; it is very tough and difficult to break. The brown variety is most usually selected by those who engage in its transmutation to diamond. This would appear to be a very simple process, as a number of corundum fragments I have examined have simply been coated with blacklead.

To avoid fraud—of which the carbon dealer may be entirely innocent—it is always a safe precaution to thoroughly wash all new parcels of stones, and examine them separately under a magnifying-glass, having a tried stone for comparison, picking out any that are of a brownish colour. If doubt exists as to the genuineness of any, test by specific gravity, which will at once prove the truth or otherwise of the suspicion.

It is wise when buying parcels of carbons to have the right to return any stones which are not up to standard. This can always be arranged with the dealers, provided the stones are returned within reasonable time, and in the same condition as when they were taken.

The time to guard against deception of the nature just described is when carbons, owing to a local heavy demand and scanty supply, run to fabulous prices, as in the Transvaal in 1896, when they reached the enormous figure of £14 per carat.

The best-shaped stones for cutting are those nuggety in shape, with well-defined angular projections. Flat stones are to be avoided, first, because of their liability to "fly," and secondly, of the difficulty of keeping them securely in the setting.

The "boort" of South Africa—a valueless stone as a gem—is sometimes employed in boring in coal formations by hand drill. Its extremely crystalline nature, and strong tendency to "fly" when boring in hard rocks, or when run at the speed required in machine drilling, render it valueless for that purpose. Even for hand work the writer is not disposed to believe that any saving is effected in its use. As a makeshift, during times when Brazilian diamonds are "cornered," and run up to high figures per carat, doubtless for the work mentioned this stone may be profitably used; but in times when the supply of black carbon is equal to the demand, and the price may be said to be normal, the extra cutting-power of the black stone, and its molecular structure, which is practically proof against chipping, make it the cheaper article in the long run.

Other varieties of diamonds, as the white and yellow, are only used in case the price of the black diamond becomes excessively high, owing to abnormal demand and shortness of supply.

Number and Weight of Stones in Boring-bit.—The number of stones used in the setting of a diamond drilling bit or crown (see Fig. 26) varies with the individual opinion of the person in charge of drills. Probably, if the average were taken of the number used by ten first-class drillmen, it would be found to be eight. The maximum weight of the stones employed rarely exceeds 3½ carats, and they are used from that weight down to a minimum of, say, 1 carat.

Wear of Carbons.—Here, similarly to the wear of the metal bit, the abrasion is dependent upon the hardness of the rocks, the setting of the carbons, and the care and judgment exercised in the running of the drill.

Given that every precaution has been taken, and that the drill is boring in rock of a hardness of 7, the wear of diamonds will average about 1 carat for every 15 feet bored. The cost per foot may, therefore, be calculated from the prevailing market rates for carbon.

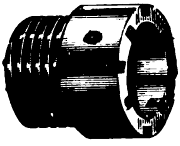

FIG. 26.—BORING BIT.

In my experience this has ranged between 60s. and 280s., hence, whereas the cost per foot in the first case would total only 4s., in the second it would figure as 18s. 8d. It is in instances such as the latter that it may be found cheaper to use more carats, of cheaper and inferior quality stones, for the performance of equal footage.

Life of a Crown.—This, obviously, is entirely dependent on the hardness of the rock which it is boring. In the dolomites of the Transvaal hornstone bands are of common occurrence, whilst the diabases frequently attain a hardness of about 8, taking 10 as a maximum.

Boring in such rocks means great attrition on both carbons and metal, and a resetting is required, say, every 10 feet. In ordinary sandstone and quartzite formation, on the other hand, a crown will last without resetting for from 20 to 30 feet. In this—as in all matters in connection with the duty of diamond drills, and assuming the stones are well set—much depends upon the skill of the man in charge, that is, (1) as to his judgment in the matter of rock hardness; (2) of the speed which the machine should run in rocks of varying hardness; and (3) as to the rate of feed allowable therein, consistent with maximum economic performance.

It is false economy to take, as it were, the last farthing from the life of the metal crown; first, because there may be insufficient iron for the gripping of the carbon; secondly, because the proportion of the carbon projection is great, and, therefore, the stones having insufficient metal are liable to chip; and thirdly, because in the majority of instances it will be found that the hole has so decreased in diameter that it is necessary to enlarge it by reaming before a new full-metalled crown will follow.

It is therefore wise to err on the side of too frequent rejection of crowns that may be only partially worn, than to risk the losses involved in repeated setting or too great wear.

A metal bit will safely carry carbons through rocks of a hardness of 7, for an average distance of from 80 to 100 feet. This allows for three settings of the entire crown of stones. After the third setting is worn below minimum gauge, the iron will be found to have become so reduced in the operation of boring—notwithstanding the protection afforded by the carbons—that there is insufficient grip for these latter, hence the rejection of the crown.

The carbons are extracted from the worn-out bit and reset in a new bit for further duty.

Cost of Bits per foot.—The cost of metal bits may be averaged at one penny a foot for holes of diameter up to 2 inches.

Water.—This element is a *sine quâ non* of diamond-drilling operations, and the position of a supply is a very important consideration when such are in contemplation. Unfortunately, it most frequently happens that the supply is fixed at a point from whence it is necessary to transport it by sleigh or waggon. In such cases the water-cost figures as an important item under conditions which do not involve more than a normal loss of water, normal being placed at 25 per cent. of the day's requirements. When the loss is greater, owing to fissures in the rock, the cost is very serious, as the total quantity pumped into the drill-hole may be lost.

It occasionally chances that water can be led on to the drill with sufficient head for working the hydraulic feed without the necessity of pumping. In mountainous districts this should be borne in mind, as the total cost for the hole, or holes, would be the amount required to pipe the water to the drill, as against the continuous cost for fuel in pumping. In this case, also, the water would be connected to the water-swivel on the drill-rods, in place of the pump connection.

In some localities a strong water supply can be obtained by sinking a well, or a series of shallow pits is sometimes more convenient. If these are near enough to the drill, the water can be delivered to the storage tanks by a hand pump, and the loss made up by constant or intermittent pumping, as required. When the source of water supply is some distance removed, tanks mounted on skids, or wheels, and drawn by horses, mules, or oxen, must be employed. The cost of this method will range between £2 and £3 per day, which, on an average cutting of 25 feet per day, is equal to 2s. 4d. per foot; and if the rock is badly fissured the distance, and hence the time, may preclude the possibility of keeping enough water for constant running in the storage tanks—assuming always, of course, that every means of stopping the leakage has been tried. The only method then open is either greatly to increase the storage capacity, and get a stock in hand before restarting the drill, or, alternatively, to run only one shift instead of two per day.

The quantity of water used in rocks where no fissures exist may be taken as the number of gallons evaporated by the boiler, *plus* a loss of 25 per cent. for waste, leakage, etc.

The supply available should be equal to the loss of the entire water pumped into the drill-rods, plus the amount used by the boiler, or say, a minimum of 15,000 gallons per day.

Fuel.—This item of cost varies in accordance with the situation of the borehole, in respect of the locality of coal deposits or timber regions.

In the Transvaal it is necessary to employ coal, because of the almost absolute dearth of indigenous trees. In my experience the cost of coal delivered at the drill has varied from 25s. to 50s. per ton, the higher price being due to distance and difficulty of transport.

The actual cost per foot for a hole 1,585 feet deep, where coal cost 35s. per ton delivered at the drill, was 2s.

With the price of coal at 25s. per ton the cost per foot cannot be reckoned, for holes 1,000 feet in depth, in rocks of a hardness of 7, at less than 1s. 3d. to 1s. 6d. per foot. This figure is, of course, out of all proportion to the economic efficiency of a good coal; but it must be remembered, (1) that boilers are generally exposed to the weather; (2) that they suffer from want of proper attention at the hands of Kafir firemen; and (3) that the quality of the coal is very inferior in comparison with best English or American coal. If wood be used, it may be reckoned that 2½ tons of wood are required to every ton of coal.

CHAPTER IX.

ON THE COMPUTATION OF THE DIP AND STRIKE OF A FORMATION.

If the strike of a particular formation cannot be ascertained from superficial observation, the subjoined method, which has been successfully used by the author, may be employed for its solution from the data afforded by three boreholes.

The formula, which is taken from Mr. Bennett H. Brough's "Treatise on Mine-Surveying" * (sixth edition, page 253), is given here *in extenso* by that author's permission.

It is assumed that three drill-holes, not in a straight line, have intersected the same formation or mineral bed at different depths, as in Fig. 27. The problem is then solved as follows:—

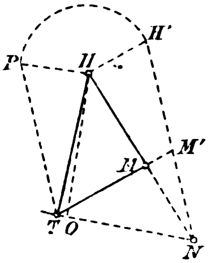

Fig. 27. — Diagram illustrating Computation of Dip of Rock from three Boreholes.

"Measure the depths of the three boreholes from the same assumed horizontal plane at the surface. In the assumed case, T represents the deepest, and H the highest point of the deposit. Imagine perpendiculars to be erected to H M at the points H and M, and on

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* London: Charles Griffin & Co., Limited.

them laid off the heights H H′ and M M′, representing the heights that the floor of the seam at the boreholes H and M is above the floor at the borehole T. In this way H′ M′ represents the line of inclination of the seam between H and M. That line is produced until it cuts the line H M produced at N. Thus a point in the seam is determined, which is situated at the same level as the bottom of the borehole T, and T N is the line of strike of the seam.

"The line H N is found, from the similar right-angled triangles H H′ N and M M′ N, to be equal to

$$\text{H N} = \frac{\text{H H}' \cdot \text{H M}}{\text{H H}' - \text{M M}'} \quad . \; . \; . \; . \; . \; . \; . \quad (1)$$

From the boreholes, the strike of H T and the angle N H T are known, and as H N is found from Equation 1, in the triangle H N T there are two sides and the included angle known, consequently

$$\text{H N} + \text{H T} : \text{H N} - \text{H T} = \tan \tfrac{1}{2} (\text{T} + \text{N}) : \tan \tfrac{1}{2} (\text{T} - \text{N}) \quad . \quad (2)$$

From this, the angles T and N are found, as half their sum is known. From the given strike H T and the angle T, the strike of the line T N may be deduced.

"In order to determine the dip of the deposit, imagine a line H O drawn from H perpendicular to the line of strike T N, then in the right-angled triangle H O T, $\frac{\text{H O}}{\text{H T}} = \sin \text{T}$, whence it follows that H O = H T sin T.

"At the point H erect a line perpendicular to H O, and along it lay-off the height H P, being the height which the floor of the seam in the borehole H is above that in the borehole T. Then the line obtained O P is the true line of dip, and the angle H O P represents the angle of dip of the deposit. Thus $\tan \text{H O P} = \frac{\text{H P}}{\text{H O}}$, or by substitution, $\tan \text{H O P} = \frac{\text{H P}}{\text{H T} \sin \text{T}}$.

"Expressed by general formulæ,

$$\tan \text{S} = \frac{d'}{a \sin \text{V}}, \text{ and } \tan \text{V} = \frac{\frac{d\,a'}{d'} \sin \text{W}}{a - \frac{d\,a'}{d'}, \cos \text{W}}$$

in which S is the angle of dip of the bed, V the angle between the strike of the bed and M H, a the distance from M to H, a' the distance from M to T, W the angle in a horizontal plane between M H and M T, d the difference of the depths of the boreholes M and H, and d' the difference of the depths of M and T.

"For example, let H T = 150 yards,
H M = 112 yards, and
M T = 100 yards, measured horizontally.

Let the angle M H T = 41° 48′ 37″, and let T be the deepest borehole, and the floor of the seam in the borehole M be 32 yards, and in the borehole H 73 yards, higher than in the borehole T. It is required to determine the strike and dip of the seam, when T H courses 172° 30′.

"From the first equation given,

$$\text{H N} = \frac{73 \times 112}{73 - 32} = 199{\cdot}41 \text{ yards.}$$

"Now, $\text{T} + \text{N} = 180° - 41° 48' 37'' = 138° 11' 23''$, and half $\text{T} + \text{N} = 69° 5' 41{\cdot}5''$. From the second equation

$$\tan \frac{\text{T} - \text{N}}{2} = \frac{199{\cdot}41 - 150}{199{\cdot}41 + 150} \cdot \tan 69^\circ\ 5'\ 41{\cdot}5''$$

$$= \frac{49{\cdot}41}{349{\cdot}41} \cdot \tan 69^\circ\ 5'\ 41{\cdot}5''$$

"From this, half T — N is found by logarithms to be 20° 18′ 55″. Half T + N being 69° 5′ 41·5″, T is equal to 89° 24′ 36·5″, and N is equal to 48° 46′ 46·5″.

"As the strike of T H is 172° 30′, and as T N lies to the right of T H, the strike of the latter is

$$(172^\circ\ 30' + 89^\circ\ 24'\ 36{\cdot}5'') - 180^\circ = 81^\circ\ 54'\ 36{\cdot}5''.$$

"The angle of dip H O P is found from the equation

$$\tan \text{H O P} = \frac{73}{150 \cdot \sin 89^\circ\ 24'\ 36{\cdot}5''}$$

By aid of logarithms, the angle H O P is found to be 25° 57′ 7″."

The strike of the reef is therefore 81° 54′ 36·5″, and its dip 25° 57′ 7″.

CHAPTER X.

DRILLING BY CONTRACT.

Diamond drilling on the Witwatersrand is almost universally done by contract, the reason being (1) that men with the special knowledge required are not easily available, and (2) that a Mining Company seldom has sufficient work to justify the outlay upon the plant; and, moreover, the saving that would be effected by the Company, as against the contractor's figure, is not sufficient to warrant the establishment of this separate department.

At the present time, the average tender for a hole 3,000 feet deep on the Rand will work out at about 37s. 6d. per foot, the price being fixed on a sliding scale, as to say 25s. for the first 500 feet, and rising by 5s. per foot each 100 feet thereafter, the contractor undertaking to supply everything in the way of plant, labour, materials, fuel, water, etc.

Now, if the Company undertook the work on its own account, the cost would be somewhat as follows:—

	£	s.	d.
A "K" Sullivan Diamond Drill, complete with all connections, and ready to work, would cost in the Witwatersrand district . . .	1,800	0	0
One 50 feet tubular four-leg derrick, erected	175	0	0
Water-tanks	50	0	0
Core-boxes	100	0	0
Lean-to over Drill	75	0	0
Quarters for Drill Runners . .	120	0	0
" Kafirs	20	0	0
Total . . .	£2,340	0	0

The average cutting rate over the total depth of hole would not be more than 300 feet per month, when allowances are made for breakdowns, delays, etc.

The monthly cost to run this machine, including 10 per cent. per annum for depreciation, would be about £400, which, divided by the footage performed, brings the cost out at 26s. 8d. per foot.

	£	s.	d.
Then, 3,000 feet at 26s. 8d. per foot	3,950	0	0
Cost of drilling outfit . . .	2,340	0	0
Total cost of hole . .	£6,290	0	0
Contractor's price, 3,000 feet at 37s. 6d.	£5,625	0	0

The Company has still, of course, as an asset, the drilling outfit, but this could not be figured upon to realise more than 50 per cent. of the initial cost, and it could only be sold even at that amount in the event of there being some demand.

If, however, a Company were to contemplate the prospecting of properties extensively by diamond drill, there is no doubt that the work departmentally done would be cheaper than contract work.

CHAPTER XI.

THE SULLIVAN MACHINERY COMPANY'S DRILLS.

From the description and remarks upon the salient features of diamond-drilling machines, it will be obvious to the reader that the Sullivan Machinery Co.'s machines fulfil more perfectly than those of any other make the exacting requirements of such an apparatus.

The marked difference in the principles underlying the operation of these machines and those of the Bullock Company's machines lies in the manner of feeding the cutting-bit through the rocks from which it is desired to obtain core.

It has been shown, in the description of various feeds, that the principles may be stated as—

1. A constant pressure in the Sullivan drill.
2. A constant rate of advance in the Bullock.

In my remarks touching upon this subject I have, I believe, clearly shown that the hydraulic principle is indubitably the one which meets most completely the varying difficulties which are presented against regular and successful feed; and in other directions—namely, in the engines, hoist, and general apparatus — these drills are models of good design and workmanship, surpassed by none. A general description of each machine is appended.

SULLIVAN "K" DRILL.

This is a premier machine, and probably the most powerful diamond drill the world produces. It embodies the very latest practice in the design of diamond drills, and is fitted with very powerful engines, many different combinations of hoist, and sliding arrangements similar to that described in connection with the "P" drill. It is shown in elevation in the Frontispiece, *ante.*

The capacity of this machine is: Holes one mile in depth. The diameters of holes and core are as follow:—

Depth of hole.	Diameter of hole.	Diameter of core.
1,000	3¾ inches.	2⅞ inches.
1,000 to 3,000	3¼ "	2⅜ "
3,000 to 5,000	2¾ "	2 "

"P" DRILL.

Capacity: 4,000 ft. in depth; diameter of hole, 1¾ in.

The engines of the "P" are similar to those of the "B" drill, but much more powerful. Its hoisting arrangement is very complete, consisting of—

1. A friction hoist, in which a grooved wheel is pressed by a hand lever into a raised V in the drum, turning it at the rate of one revolution to four of the engine.
2. A direct hoist, with ratio of 1 to 11, changeable by means of a set of back-gears to a ratio of 1 to 33, or by a second set of back-gears a ratio of 1 to 50.

By this arrangement a hoisting speed can be used, adapted always to the weight of the rods to be raised, and as the different combinations can be thrown in or out in a few seconds, several speeds may be used in one pull, thus saving considerable time when hoisting from great depths.

As this drill on its base-plate is too heavy to be easily slidden back and forth on the frame, in the manner employed in the smaller machines, a special device is fitted to it for that purpose. This consists of two axles, passing through the base-plate, with wheels at their end, and hand levers keyed on to the axles. With levers, the wheels are raised off the frame, and the base-plate clamped down to it. Raising the lever to a vertical position loosens the clamps by means of cams on the axle, and at the same time lowers the wheels to the track and raises the base-plate to rest on the axle-wheels. The drill can then be rolled back on the frame. Reversing the operation clamps it again to the frame. Thus, in spite of the weight of so powerful a machine, the work of moving it backwards and forwards is done very quickly and easily, without danger of disturbing the setting of the machine.

For shipping weights and dimensions, see page 146.

"N" Drill.

The "N" drill (shown in Fig. 28) is arranged with extra large swivel-head, drive-rod, and hydraulic cylinder for drilling a $2\frac{3}{4}$-inch hole, removing $1\frac{7}{8}$-inch core. This size of core is specially suitable when boring in soft formation, such as coal, etc.

Some idea of the power of this drill, manifesting

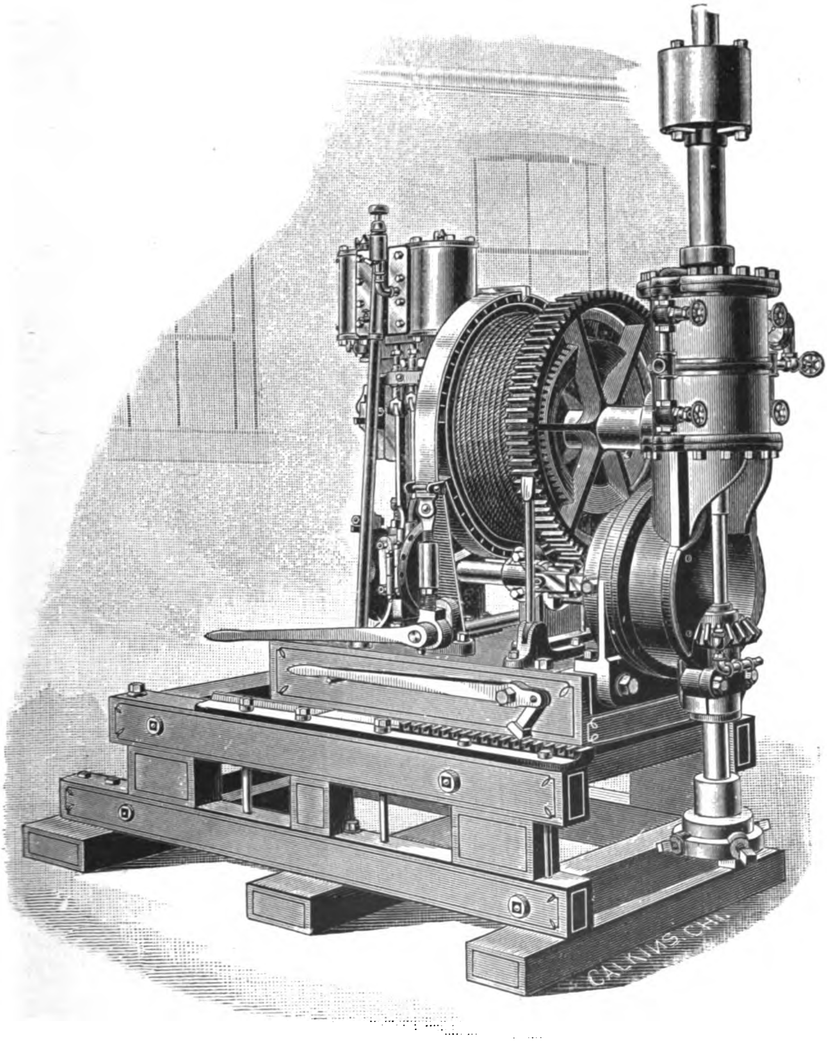

FIG. 28.—SULLIVAN "N" DRILL.

one of the special advantages of the hydraulic feed, can be gained from the following statement:—

The hydraulic piston, 11 inches in diameter, can at any time be instantly subjected to a hydraulic pressure of at least 180 lbs. per square inch, giving a total pressure of over 15,000 lbs. immediately available for raising the rods whilst the drill is running, in case of any threatened wedging in the hole.

For shipping weights and dimensions, see page 146.

"B" DRILL.

The engine, hoisting rig, and feed works of this machine are strongly built for deep work. The machine is fitted with two rates of hoisting gear, which are proportioned, the one for a heavy weight of rods, when the drum makes 1 revolution to 39 of the engine, and the other for use in lighter work, in shallower depths, when a direct gearing of 1 to 13 may be employed, thus allowing quick speed in hoisting light loads. One revolution of the drum winds up about 6 feet of rope.

Holes have been drilled with this machine up to 2,350 feet in depth without counterbalancing the drill-rods.

The equipment furnished with this drill, and included in the price, is given on page 140. For shipping weights and dimensions, see page 147.

"C" DRILL.

This machine, with its hoisting apparatus and some other details, is modelled after the "B" drill. It gives excellent results, either in shallow holes or in those attaining its maximum capacity, and is shown in Fig. 29.

An illustration of the hoist has already been given in Fig. 17, p. 43.

Although intended principally for surface work, the "C" drill may be conveniently used, either at the bottom of a shaft, or in a drift or stope, when it is required to penetrate to distances beyond the capacity of the "E" drill.

The equipment furnished with this drill, and included in the price, is given on page 140, and the shipping weights and dimensions on page 147.

"H" Drill.

This machine, though smaller, is proportionately as well and strongly built as the large sizes.

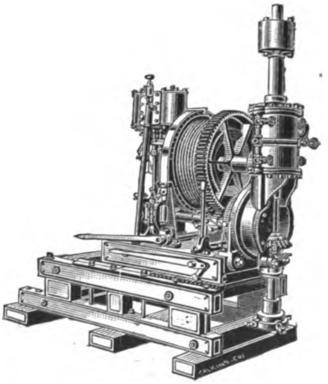
Fig. 29.—Sullivan "C" Drill.

The annexed cut, Fig. 30 (already given at page 63), shows one way of setting up the Sullivan hydraulic feed machines, and of making the necessary steam and water connections to boiler and pump. The upper steam-joint near the engines is a union, which is swivelled so as to allow the drill to move back and forward when drilling and hoisting, without breaking the joint. This connection is preferably made with steam hose, which allows of greater freedom of motion. The vertical pipe, marked "Standard," is plugged or solid, and acts only as a support to the steam-pipe above.

In setting up the larger sizes of drills, the Duplex pump used with them is placed beside the frame, usually at the left of the drill, as shown in illustration here given, for convenience in piping to the boiler.

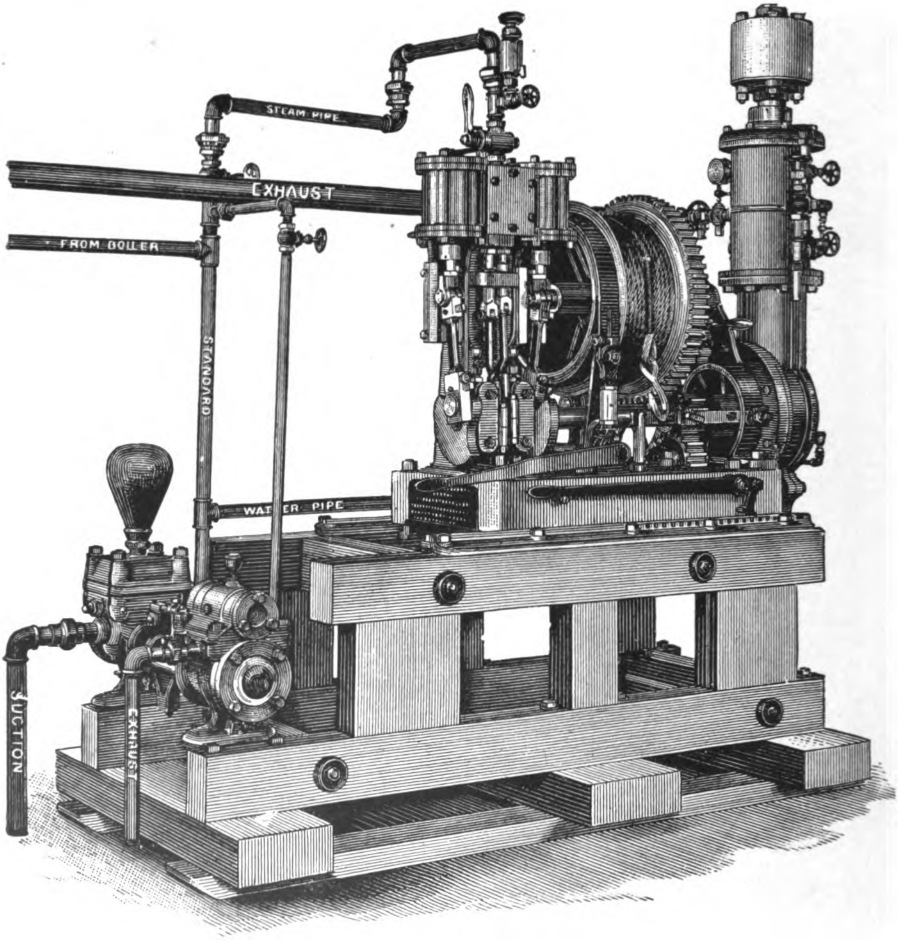

FIG. 30.—SULLIVAN "H" DRILL.

The equipment furnished with this drill, and included in the price, is given on page 140, and the shipping weights and dimensions on page 147.

"A" Drill.

The cut shows the hydraulic apparatus set at an angle, by means of its swivelled connection to the frame of the machine, allowing of holes being drilled at any angle from the vertical to horizontal. In all important respects this machine is similar to the larger "C" machine.

The equipment furnished with this drill, and included in the price, is given on page 140, and the shipping weights and dimensions on page 147.

"S" Drill.

In order to provide a diamond drill possessing some of the features of both surface and underground prospecting drills, the "S" machine has been designed. It has a frame and hoist similar to those used on the hydraulic feed machine for surface prospection, and is fitted with patent friction feed, which is compact for underground work.

Its friction feed is the same as that used on the "E," "G," "M," and "R" drills.

Since the annexed cut (Fig. 31) was made, this drill has been improved by a compact and strong system of back-gearing, which adds to its efficiency.

The "S" drill can be used either on the surface or underground.

For shipping weights and dimensions, see page 148.

"M" Drill.

To meet the demand for a cheap, but accurate, diamond drill, suitable for shallow holes in soft formation, the "M" drill, operated by (1) hand power, (2) belt from a horse-power gear, or (3) portable engine, has been designed.

This machine is mounted on hollow standards, with hollow back-braces, an arrangement which combines strength, rigidity, and lightness. Binding clamps allow change of position up or down the standards.

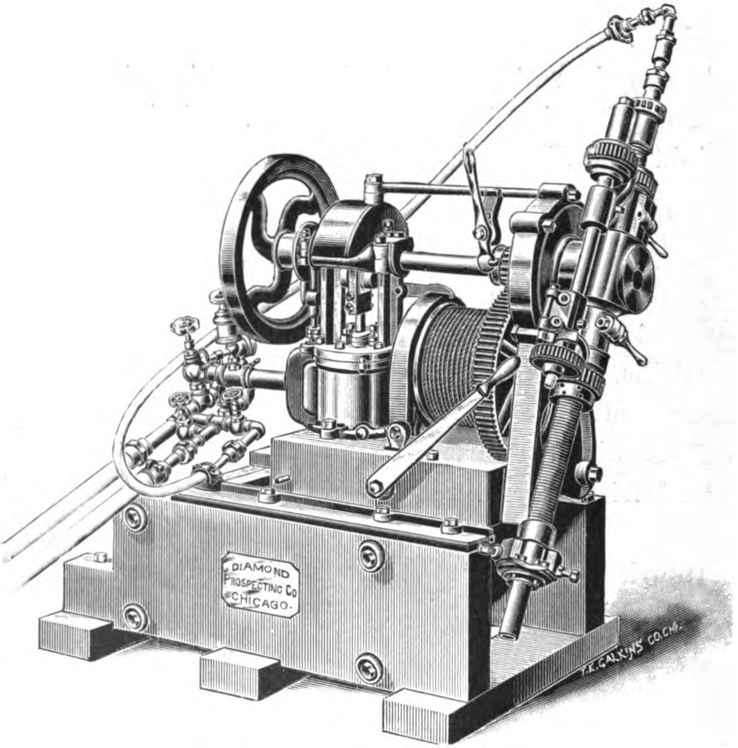

FIG. 31.—SULLIVAN "S" DRILL.

A swivel-joint in line with the crank-shaft enables the machine to be turned at any desired angle.

The machine is built with the same care as the steam drill, and is fitted with friction-feed gear.

The hand power hoist, shown in cut, consisting of drum gears and wire rope with hook, is not included in the regular drill equipment, but is a useful appliance, and more speedy than the usual rope and block.

The equipment furnished with this drill, and included in the price, is shown on page 143, and for shipping weights and dimensions, page 148.

"G" DRILL.

This drill embodies the same general principles, and is of the same capacity as the "E," with some differences of detail. The drill-rods in this machine are screwed to the lower end of the feed-screw without the interposition of a drive-chuck. It is provided with friction feed, and is specially adapted for horizontal prospecting underground.

For equipment furnished with the "G" drill, and included in the price, see page 142, and for shipping weights and dimensions, page 148.

"E" DRILL.

This machine (Fig. 32) has been specially designed for underground prospecting. For such work, a drill must embody many of the features of the surface machine, but in particular must be so constructed that it may be easily operated in a limited space, light, and easily taken apart for facility in transportation underground from one point to another. The "E" drill possesses all these requirements.

It is supported directly between the standards, so that the line of greatest pressure coincides with the line of greatest resistance, and there is, therefore, no tendency for the drill to twist and get out of line with the hole.

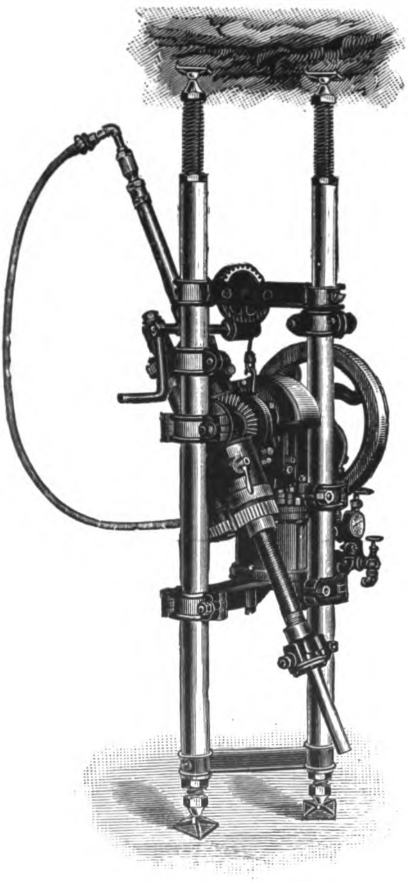

Fig. 32.—Sullivan "E" Drill.

In addition to the pressure resistance given by the standards, there is a system of braces, not shown in the cut, which are adjusted directly opposite to the thrust of the rod, thus making the drill rigid when drilling at any angle. The machine is provided with a spool on the crank shaft, by means of which the rods can be hoisted by power.

The small size and weight of this drill, as shown below, and the fact that it can be taken apart or set up in 15 minutes, makes it particularly useful in mine workings.

Weight of drill set up complete, 580 lbs.

Heaviest piece, 125 lbs. No other piece comes over 75 lbs.

Space required in line of drill-rods, 6 feet 6 inches.

Width required, 2 feet 2 inches.

Height required, 5 feet 8 inches.

For equipment furnished with this drill, and included in the price, see page 142, and for shipping weights and dimensions, page 148.

SUMMARY OF THE SULLIVAN COMPANY DRILLS.

Price F. O. B., Chicago.	Size of Drill.	Capacity.		Diam. of Core.	Steam-pipe.	Ex-haust-pipe.	Pump required.	Boiler required for drill and pump.	Space required. Drive-rod in lowest position.	
		Depth of Hole.	Diam. of Hole.						Floor space.	Height.
£		Ft.	In.	In.	In.	In.		H.P.	Ft. in. Ft. in.	Ft. in.
	A	1,500	$1\frac{3}{4}$	$1\frac{1}{8}$	1	$1\frac{1}{2}$	$6 \times 3 \times 7$	12	3 6 × 6 3	6 9
604	B	3,000	2	$1\frac{3}{8}$	$1\frac{1}{4}$	2	$6 \times 3 \times 7$	15	3 9 × 7 0	7 6
508	C	1,500	$1\frac{3}{4}$	$1\frac{1}{8}$	1	$1\frac{1}{2}$	$6 \times 3 \times 7$	12	3 6 × 6 3	6 9
180	E	400	$1\frac{1}{2}$	$\frac{15}{16}$	1	$1\frac{1}{4}$	$4\frac{1}{2} \times 2\frac{3}{8} \times 5$	8	—	—
	G	300	$1\frac{1}{2}$	$\frac{15}{16}$	1	$1\frac{1}{4}$	$4\frac{1}{2} \times 2\frac{3}{8} \times 5$	8	—	—
370	H	1,000	$1\frac{3}{4}$	$1\frac{1}{8}$	1	$1\frac{1}{2}$	$4\frac{1}{2} \times 2\frac{3}{8} \times 5$	10	3 2 × 6 3	6 6
85	M	300	$1\frac{1}{2}$	$\frac{15}{16}$			Hand	or belt	power drill	
690	N	2,000	$2\frac{3}{4}$	$1\frac{7}{8}$	$1\frac{1}{4}$	2	$6 \times 3 \times 7$	20	3 9 × 7 3	7 6
840	P	4,000	$2\frac{3}{4}$	$1\frac{7}{8}$	$1\frac{1}{4}$	2	$8 \times 4 \times 12$	25	4 1 × 7 6	10 6
320	R	500	$1\frac{1}{2}$	$\frac{15}{16}$	Electro	motor	attached		2 6 × 3 6	4 3
250	S	500	$1\frac{1}{2}$	$\frac{15}{16}$	1	$1\frac{1}{4}$	$4\frac{1}{2} \times 2\frac{3}{8} \times 5$	8	2 7 × 4 3	4 3

The above prices are *not* inclusive of the extra equipment, elsewhere specified.

CHAPTER XII.

THE BULLOCK MACHINERY COMPANY'S DRILLS.

THE diamond-drilling machines manufactured by the M. C. Bullock Manufacturing Company are models of compactness and finish. The machines through which the Company is best known are those provided with a positive-screw feed, described in a preceding chapter. In the description of the different feeds employed upon diamond-drilling work it is shown that the hydraulic feed embodies more of the elements of a theoretically perfect arrangement than either of its competitors.

The Bullock Company, doubtless recognising this, have now perfected a machine, fitted with a hydraulic feed, which is certain to be up to their first-class standard of work. The addition of this feed will, in my opinion, recommend the machine to many men who are prejudiced against positive-feed drills.

Although I have stated my bias in favour of hydraulic feed, I do not by any means wish to detract from the performance of the Bullock positive-feed machine, whose record of work successfully completed is its own recommendation. Of its type, the machine is in the van, but to get the maximum work from it requires more careful attention than does a machine fitted with a hydraulic feed, for the reasons elsewhere enumerated, and hence the probability that, in the majority of instances, work done by the hydraulic-feed machines and the positive-feed, under the same conditions, would come out in favour of the former, both on cost for losses in carbons and time absorbed in drilling a certain footage.

In boring through strata which is throughout of the same hardness, as in the coal-measure sandstones, in limestone, granite, porphyry, etc., the positive-feed machine should, theoretically, give results of the very highest standard, since, once set in such rocks, its rate of advance is absolutely governed by the setting of the gear and the speed of the engine. In practice, however, variation in hardness of rocks of the same constitution is the rule and not the exception, the degree of hardness varying with the rock's molecular structure.

Whilst, therefore, regarding the Bullock positive-feed machine as the highest-grade machine of its class, I strongly advocate the greater range of suitability of the hydraulic-feed machine.

All the Bullock machines are fitted with a very ingenious and important device by which the careful drill runner is immediately informed of occurrences in the drill-hole, indicating, according to the registered pressure, the following items:—

1. The passage of the bit from one rock to another—whilst the drill is running—without depending upon the drill-cuttings or the core saved.
2. The wedging of the core in the barrel.
3. The rate of forward feed suitable to the rock's hardness.

4. The striking of a fissure.
5. The width of the fissure.

The arrangement is named the "Patent Thrust Register." In an ingenious manner the thrust of the drilling-bit is communicated to a hydraulic vat, which acts upon a pressure gauge, placed in full view of the drill operator. The thrust of the bit varies according to the hardness of the formation—the thrust being that particular return pressure expressed by the difficulty encountered in piercing the rock; and the said thrust communicating its proportionate value to the hydraulic vat is registered upon a gauge connected therewith. When, therefore, the bit is passing through a fissure the gauge will stand at zero; upon its re-engagement with the rock it will indicate a pressure that will inform the drill runner of the nature of the rock; whilst, if feeding too fast, or if the core-barrel is wedged, the extreme pressure registered denotes these.

It is quite possible, however, in a hydraulic-feed machine to judge of any of these points from the sensitiveness of the diamond crown to the constant pressure in the hydraulic cylinder, which sensitiveness is communicated to the runner by means of a gauge and a figured bevelled margin, from which any variation in the rate of cutting is instantly discernible.

The drills are provided with the Bullock patent swivel-head, carrying the feed apparatus and driving-gear. The Bullock Company claim a great advantage in the use of this head, which by the loosening of one nut can be swung out of the way, leaving the front of the machine clear for hoisting drill-rods, and by loosening two nuts at the back of the machine, can be adjusted to bore holes at any angle.

The swivel-head is carried on a main frame steel casting, and is attached to the drill by a hinge connection to a steel yoke, carried on the front standard of the machine. The swivel-head is locked into position by means of a single bolt. When a "run" is completed, and it is desired to hoist the rods to surface, they are first securely caught by a clamp, and the top rod is unscrewed and taken out. The swivel-head is then swung back out of the way, after the removal of the lock-nut, and the front of the machine is clear for the hoisting of the rods and returning them again to the hole.

Before the return of the last rod the swivel head is swung back into place, locked, and the top rod inserted through the feed-screw and the machine is ready for drilling. The whole operation has been completed without moving the machine from its original setting, thus lessening any liability of getting it out of line with the hole.

Objection is made to this style of swivel-head by some, on the grounds that it is insecure and unsafe to withstand the heavy thrust of the drill when boring in hard rock. The record of the machine, however, is a full refutation of such statements.

A general description of the best-known machines is given hereunder.

THE "BEAUTY."

The "Beauty" (illustrated in Fig. 33) has two compact engines, of trunk style, set at right angles, thus avoiding dead centres. The valves, ports, and passages are short, and directly adapted to the practical and economical use of either compressed air or steam. The crank-shafts, crank-pin, and eccentrics are forged from a

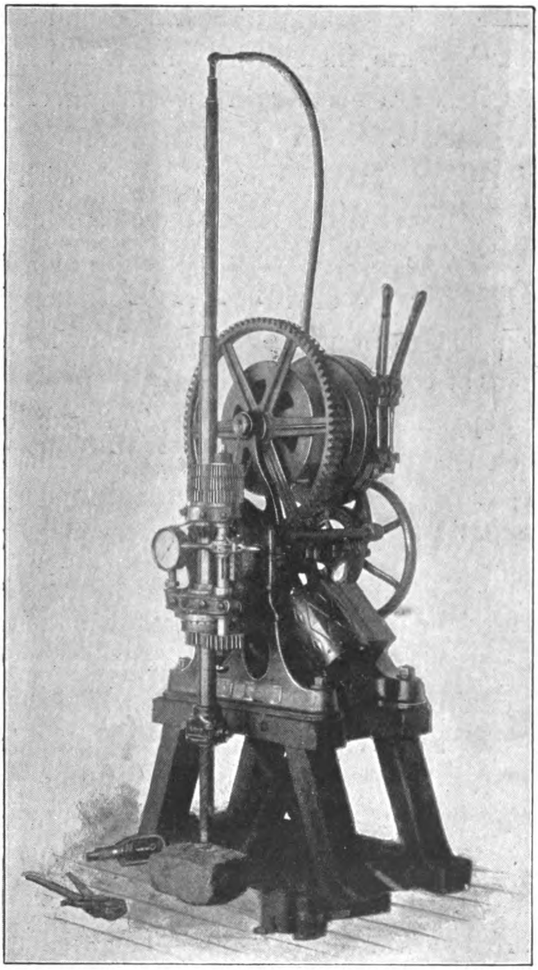

FIG. 33.—BULLOCK "BEAUTY" DRILL.

single piece of steel, which is bored out and made hollow, and arranged to oil all running parts from its outer end.

The shaft and crank pin bearings and all other wearing surfaces are lined with composition brass. The connecting rods are made with hardened steel bearings at their lower ends.

The swivel-head of the "Beauty" is made with a patent hinge-plate, which by the loosening of one nut can be swung out of the way, leaving the front of the machine clear for hoisting the drill-rods, and by loosening two nuts at the back of the machine can be easily adjusted to bore holes at any desired angle.

The feed apparatus of this machine is a modification of the Bullock Standard type, and can be described briefly as follows:—

The drill-rods pass through a hollow steel feed-screw, upon the lower end of which is secured a cast-steel chuck which clamps the drill-rods, carrying them with it. On the outside of this feed-screw is cut a square thread with a spline running its entire length, by which the spindle is driven direct from the engine-shaft by a pair of machine-cut, steel-bevel gears. The pressure required to force the bit into the rock is transferred through the feed-screw and steel nut, and taken up by a patent roller thrust bearing.

There are two sets of feed-gears, mounted upon the screw and counter-shaft, and by means of clutch and detent the operator can instantly change the feed from one to the other while the drill is running, thus adapting the rate of penetration to the character of the rock encountered. When the feed-screw has travelled the full length of its run it can be run back rapidly by moving the clutch back to its lower position, ready to again engage with the rods and resume boring.

To meet the varying degree of hardness of different strata, standard rates of feeds have been selected for these machines, and several sets of feed-gears, arranged to insure the greatest cutting capacity of the diamonds, are obtainable.

The feed-gears, bevel gears, and roller bearings are all encased to protect them from dust, dirt, or injury, and to ensure the safe operation of the machine in the most confined quarters. With each machine two sets of feed-gears are furnished.

Capacity: hole, $1\frac{3}{8}$ inches diameter; $\frac{15}{16}$ inches core; depth, 800 feet.

For underground prospecting, the "Beauty" drill is mounted on a pair of light, strong columns of suitable length, adapted to the width of the gangways of a mine. The machine is rigidly secured to these supports by means of clamping devices, arranged to be quickly operated from either side of the machine. At the top of the column there is a substantial crossbar, to the centre of which is attached a wire rope, which is wound upon a reel upon the frame of the drill. This reel is provided with a crank, ratchet and pawl, by the use of which the drill can be easily and rapidly lowered or hoisted into the required position for boring a hole. The top of columns have screw extensions, by which the drill is rigidly secured in position, thus making a light, portable, and most convenient machine for handy and quick transportation from point to point, ranging from the upper to the lower levels of a mine.

In tracing ore bodies the drill can be quickly set up and put in operation, and can be used to bore holes at all angles, from vertical to horizontal.

The weight of this machine is 385 lbs., which can be readily separated into 75-lb. packages for mule-back transportation. It occupies, off the columns, a space only 20 inches square, which particularly adapts it for working in confined places. It has a capacity to operate a Class B outfit, boring $1\frac{3}{8}$-inch hole, taking out $\frac{15}{16}$-inch core to a depth of 800 feet, or Class C (special outfit) $1\frac{3}{4}$-inch hole, $1\frac{3}{16}$-inch core to a depth of 500 feet. Class B drill-rods ($1\frac{5}{16}$ inches) are used with either class of boring tools.

THE "DAUNTLESS."

The engines of this machine (Fig. 34) are 5 inches diameter by 5 inches stroke, having reciprocating cross-heads and all other necessary parts, with extra large wearing surfaces perfectly adjustable for wear.

The valves are of a new and patented form, securing extra short ports, and consequent small clearance, are nearly balanced, and cut off at $\frac{3}{4}$ stroke. Being actuated by a drag-crank, they are on the outside and easy of access, and by a new and patented arrangement the drag-crank may be moved, reversing both engines.

There are but two standards to the machine, the front carrying the swivel-head, while the rear standard forms part of the frame for the engines, and both of such form as to give the maximum of strength for the minimum of weight. The drum, holding 400 feet of ½-inch or 160 feet of ⅞-inch wire rope, is so arranged that four different speeds and powers of hoist are obtainable, viz.:—

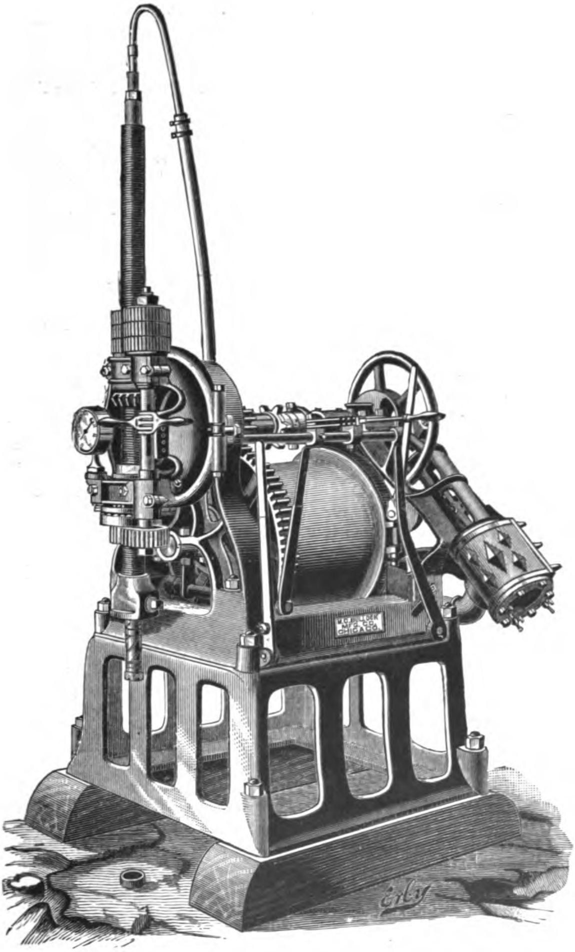

Fig. 34.—Bullock "Dauntless" Drill.

1st, about 2,200 lbs., 400 feet per minute.
2nd, „ 4,300 lbs., 200 „ „
3rd, „ 6,200 lbs., 140 „ „
4th, „ 12,000 lbs., 72 „ „

With the engine running 500 revolutions per minute, and developing about 26 horse-power.

For any combination of gearing, by simply throwing out one lever, the drum is allowed to run free on the shaft controlled by the brake, which is lined with the best friction material. By this means heavy weights may be hoisted, and dropped as rapidly as desired, for hoisting or lowering of empty tackle, or for driving stand-pipe or driving piles.

The swivel-head is capable of being swung open out of the way when handling the drill-rods, and arranged to drill a hole at any desired angle. By means of hydraulic plungers, in a cavity communicating with a pressure gauge, the fluctuations of the pressure required to feed the drill into the rock are instantly recognised. This indicates the instant the bit passes from one geological formation to another, enabling the operator to give an accurate record of the exact thickness of each stratum at any depth while the drill is running. The whole machine is neat, strong, and compact in design, made by means of a complete line of "templates and jigs," thus securing perfect interchangeability of duplicate parts.

THE "DELVER" (formerly the "CHALLENGE").

This machine (Fig. 35) is compact, strong, and symmetrical, capable of boring a hole 2½ inches diameter, taking out a solid cylindrical core 1⅞ inches diameter to a depth of 1,500 feet. It will bore a 2-inch hole, taking out a

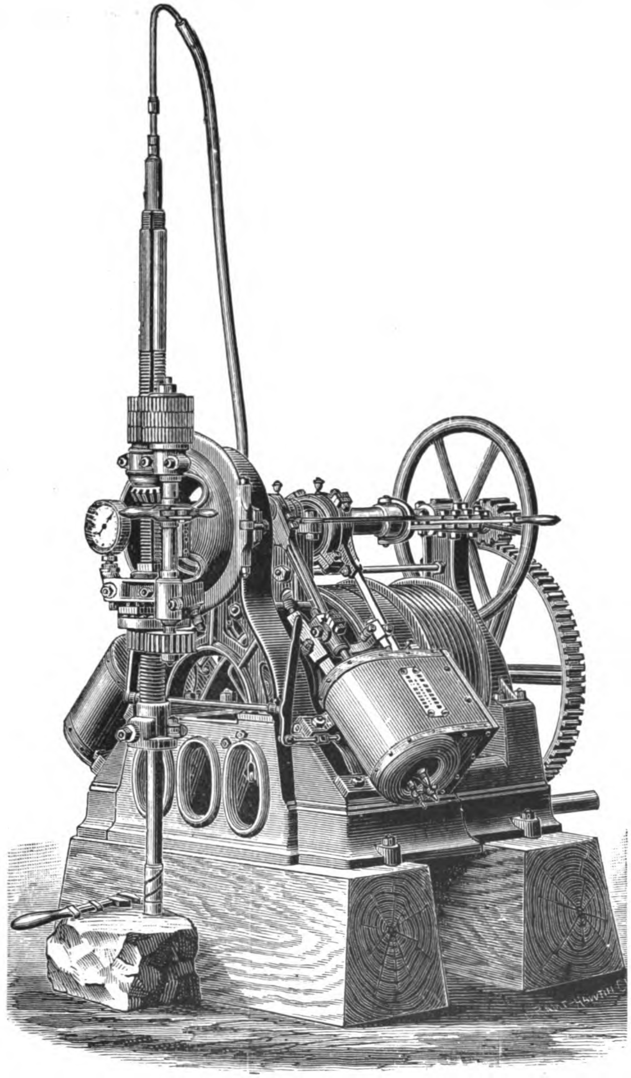

Fig. 35.—Bullock "Delver" Drill.

core $1\frac{7}{16}$ inches diameter to a depth of 2,000 to 2,500 feet.

For ordinary work in boring a 2-inch hole the outfit is similar to that furnished with the "Dauntless," excepting the boiler, which is of 15 horse-power, instead of 12 horse-power, as furnished with the "Dauntless."

"CHIEF." Class "B."

This drill is used for underground or surface prospecting, and is shown in the cut (Fig. 36) with patent hinged swivel-head, fitted with improved hydraulic feed. The main features embodied in the construction of the engines and hoist of this drill are identical with those of the "Champion."

Fitted with a Class C outfit, this machine has a capacity for boring a $1\frac{3}{4}$-inch hole, taking out a $1\frac{3}{16}$-inch core to a depth of 1,000 feet; or fitted with a Class D outfit, has a capacity for boring a 2-inch hole, taking out a $1\frac{7}{16}$-inch core to a depth of 800 feet.

"CHAMPION." Class C.

The "Champion" drill (Fig. 37) is used for surface or underground prospecting, and is mounted upon a substantial bed-plate, upon which, coupled at right angles, are a pair of Bullock's standard trunk engines, fitted with patent valves, arranged to give the highest economy of steam or compressed air. The drum has patent compound internal geared friction hoist, arranged to be operated from either side.

This machine is fitted with patent hinged swivel-head, carrying patent thrust register, positive screw-feed, and all the latest improvements, and has a capacity to operate a Class C outfit, boring a $1\frac{3}{4}$-inch hole, taking

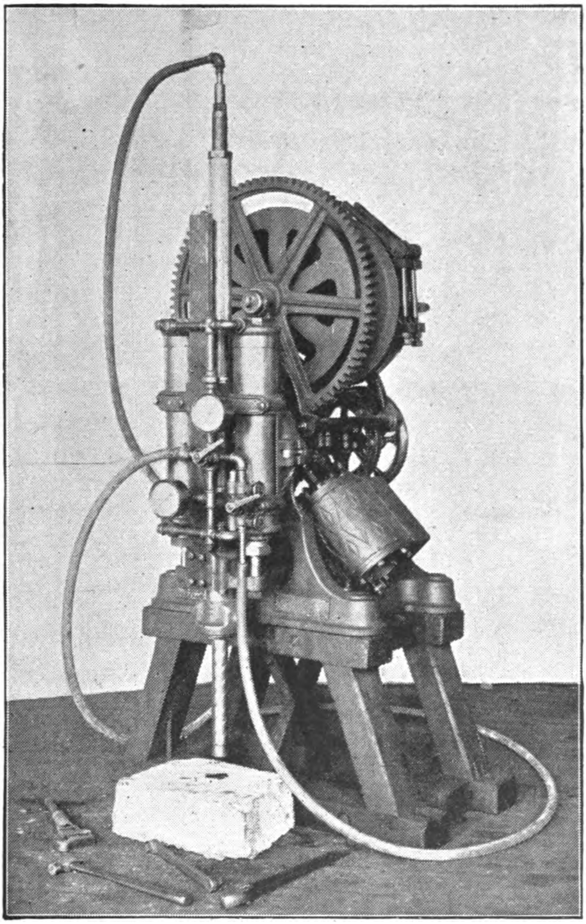

FIG. 36.—BULLOCK "CHIEF" DRILL, WITH HYDRAULIC FEED.

out a $1\frac{3}{16}$-inch core to a depth of 1,200 feet; or a Class D outfit, boring a 2-inch hole, taking out a $1\frac{7}{16}$-inch core to a depth of 1,000 feet. Weight, 1,280 lbs., which can be divided into 100-lb. packages for mule-back transportation.

SUMMARY OF THE BULLOCK COMPANY DRILLS.

The "Beauty."

Two-cylinder, for steam or compressed air.
Hole $1\frac{3}{8}$-inch, core $\frac{15}{16}$-inch, 800 feet deep.
Hole $1\frac{3}{4}$-inch, core $1\frac{3}{16}$-inch, 600 feet deep.

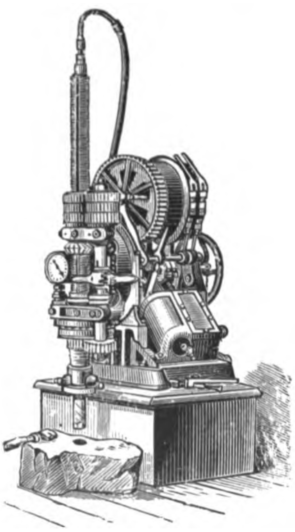

FIG. 37.—BULLOCK "CHAMPION" DRILL.

The "Dauntless."

Two-cylinder, screw feed, patent thrust register.

Hole 2-inch, core $1\frac{7}{16}$-inch, 2,000 feet deep.

Hole $2\frac{5}{8}$-inch, core 2-inch, 1,500 feet deep.

Hole $3\frac{9}{16}$-inch, core $2\frac{7}{8}$-inch, 1,200 feet deep.

The "Delver."

Two-cylinder, screw feed, patent thrust register.

Hole 2-inch, core $1\frac{7}{16}$-inch, 2,500 feet deep.

Hole $2\frac{5}{8}$-inch, core 2-inch, 2,000 feet deep.

Hole $3\frac{9}{16}$-inch, core $2\frac{7}{8}$-inch, 1,800 feet deep.

The "Chief."

Two-cylinder, hydraulic feed.
Hole $1\frac{3}{4}$-inch, core $1\frac{3}{16}$-inch, 1,000 feet deep.
Hole 2-inch, core $1\frac{7}{16}$-inch, 800 feet deep.

The "Champion."

Two-cylinder, screw feed, patent thrust register.
Hole $1\frac{3}{4}$-inch, core $1\frac{3}{16}$-inch, 1,500 feet deep.
Hole 2-inch, core $1\frac{7}{16}$-inch, 1,200 feet deep.
Hole $2\frac{5}{8}$-inch, core 2-inch, 800 feet deep.

The "Bravo" (see Hand-power Drills).

Hand power or horse power.
Hole $1\frac{3}{4}$-inch diameter, 350 feet deep by hand power.
Hole $1\frac{3}{4}$-inch diameter, 450 feet deep by horse power.
(This machine is also fitted for boring holes $1\frac{3}{8}$ diameter.)

Prices delivered in Johannesburg.

"Bravo."—400 feet outfit. Price £270. Weight, 2,150 lbs.

"Champion."—1,200 feet outfit. Price £1,150. Weight, 15,400 lbs.

"Dauntless."—2,000 feet outfit. Price £1,500. Weight, 26,400 lbs.

CHAPTER XIII.

APPARATUS USED WITH THE SULLIVAN DRILL.

Casing.—Flush joint casing is supplied by various companies. The Sullivan Machinery Company furnish a casing that has perfectly smooth joints. Such an arrangement reduces, first, the diameter to which a hole requires reaming, and secondly, the liability to catch when inserting or drawing the casing. It is made of heavy pipe, threaded in a lathe, and is generally of first-class material and workmanship.

For soft formations it is threaded left-hand, to prevent unscrewing from the bottom by the rotation of the drill-rods; and also, if it become fast, it can be "backed off" by the drill-rods and a right-hand tap. In hard formations right-hand casing is used, to allow it to be drilled into the rock by the casing-bit and rods when necessary. If right-hand casing is required to be "backed off," the rods must be pinned and a left-hand tap used.

All classes of well casing—of the highest quality, and of any strength—can be obtained from English makers, such as Russell & Sons, Spencers, and others.

TABLES OF CASING.

Nominal inside diameter, in inches.	Actual inside diameter, in inches.	Thickness, in inches.	Actual outside diameter, in inches.	Length, in feet.	Weight, in lbs.
E	1·62	0·25	2·12	10	5
2	1·93	0·22	2·37	10	5
2½	2·31	0·28	2·87	10	7½
3	2·89	0·30	3·50	10	10
3½	3·35	0·32	4·00	10	12½
4	3·81	0·34	4·50	10	15

Bail and Clevis.—This apparatus is used to suspend the rods after attachment of the water-swivel, and just prior to lowering rods to the bottom of the hole. It is constructed so that the weight of the rods is taken on the under-shoulder of the swivel, and therefore there is no danger to the swivel itself.

Water-swivel.—Two of these are obtainable, the one embodying more perfect anti-friction arrangements than the other.

The water-swivel forms the connection between the pump and the drill-rods, and is so constructed that the upper portion remains stationary, whilst the lower portion revolves with the revolutions of the rods. A stream of water is constantly forced through it, and down to the drilling-bit, through the hollow line of rods, emerging through the bit at the bottom of the hole, in its passage keeping the diamonds cool, and rising through the clearance between the rods and the sides of the drill-hole to the surface; carrying with it the cuttings from the drilling-bit.

Safety-clamp.—This tool is provided with toothed jaws, so arranged as to be closed together by the downward pull exerted by the wedging of the drill-rods, or, contrariwise, easily loosened by any upward movement. Thus the rods can at any time be pulled freely through the clamp in an upward direction, but immediately the tendency is downward the clamp-jaws, owing to their dovetailed setting, grasp the rods and sustain them until they are freed. This feature of the clamp is most important, as, in event of breakage of the hoisting-rope, or sheave, the rods are prevented from falling to the bottom of the hole by the automatic action of the jaws.

Hoisting-plug.—This appliance is used for the hoisting and lowering of the rods, and consists essentially of an eye-bolt, which is free to revolve within a socket screwed to a solid threaded boss, which fits into the ends of the drill-rods. The hoisting- rope hook, when hoisting or lowering, is attached to the eye-bolt of the hoisting-plug, and the plug is detached from each length, and re-attached to the succeeding length during the operation indicated.

Core-lifter. — Of these there are several varieties, their duty being to break and lift the core to surface. They are so constructed that they move downwards freely over the core, but resist any downward movement it may make. At the moment of first lift in the rods the core-lifter grips the core, and as the rods move upward breaks it off.

The most usual varieties of core-lifters are the two known respectively as the "split ring" core-lifter and the "cossette." The latter is undoubtedly the best, as its action is absolutely positive under any conditions, whilst the "split ring," if kept too long in use, may fail in its grip.

Drive-head and Shoe.—These appliances are used in the process of driving the stand-pipe, as explained in that connection elsewhere. The best English make are those of James Russell & Sons.

Chopping-bit.—This is made of steel, with hardened chisel-shaped edges, and is screwed to the lower end of the wash-rod. Rod and bit are then jumped up and down, as in driving the stand-pipe, to break up any existing boulders.

Core-shell.—The core-shell consists of a short tube, in which is placed the core-lifter, and to the lower end of which is screwed the diamond-bit.

Reamer.—The "short" reamer consists substantially of a hollow boss, made of soft metal, for the reception of carbons, and fitted with a guide-collar.

The "long" reamer is recommended in preference to the short one just described, as it prevents vibration, makes a straight hole, and reduces the wear of carbons. It consists of 10 feet of extra heavy pipe, which is attached to the drill-rods by a bushing, with the reamer proper at the bottom. The reamer head resembles that of the short reamer, excepting that here the guide, which is a portion of the face on the short reamer, is one piece with this head. The said guide fits into the drill-hole, and is threaded at the top to hold the face, which latter consists of a Swedish iron ring, into which the diamonds are set. Water passes through the hollow space in the reamer as it does through the bit in drilling, carrying away the cuttings in the same manner.

Recovering Taps.—These tools are used to pull the rods to surface in case of breakage or accidental dropping into the borehole.

Core-tube.—This is a tube varying in length from 10 to 20 feet, which is employed to hold the core which has passed upwards through the core-lifter in process of drilling.

Pipe-clamp.—This is a necessary contrivance for use when casing is lowered inside stand-pipe, or when any pipe lowering inside one of larger diameter. The pipe-clamp is used to hold the pipes, as each joint is made at surface prior to lowering into the hole.

Drill-rods, with Couplings.—These are simply hollow tubes, made 10 feet in length, which make up the line of drive from the engine to the drilling-bit, and, being hollow, allow of the circulation of a current of water, which is pumped through them to the said bit.

The sizes, diameters, lengths, etc., are given in the following table:—

Sizes—	A	D	E	F	N
Outside diameter, inches . .	$1\frac{5}{8}$	$1\frac{15}{16}$	$1\frac{5}{16}$	$1\frac{5}{16}$	$2\frac{3}{8}$
Length, in feet . . .	10	10	5	10	10
Weight, per 100 feet, boxed .	370	450	385	385	585
Price, per 100 feet, in Chicago .	£14	£15	£14 10s.	£12	£19
Extra couplings, each . .	5s.	5s.	4s.	4s.	6s.

The following letters used for rods, bits, core-barrels, etc., indicate the size of these fittings: as, A for $1\frac{3}{4}$-inch hole, $1\frac{3}{16}$-inch core; B for 2-inch hole, $1\frac{3}{8}$-inch core; E for $1\frac{1}{2}$-inch hole and $1\frac{7}{8}$-inch core.

In cases where circumstances render it advisable to use larger or smaller fittings than those given in the above list, or in the description of drills, the change can be readily made.

The size of the hole and core can be increased by substituting larger core-barrels, lifters, shells, and bits.

In very hard rock, however, the smaller the hole can be kept, consistent with the nature of the rock, the less the cost of the work and the better the rate of progress, whilst the accuracy of the test is the same.

Thus, in drilling hard rocks, the E fittings are frequently used on the "A," "C," "H" and "B" Drills, whilst in testing for soft minerals, as coal, the N fittings may be used on the "H" and "C" Drills. The "M" Drill can use either E or A bit, and other fittings, according as its work lies in hard or soft formation.

The	"A," "C," and "H"	Drills use	A	rods, bits,	shells,	core barrels, etc.
,,	"B"	,, ,,	D	,,	,,	,,
,,	"E," "G," "M," "R," "S"	,, ,,	E	,,	,,	,,
,,	"N" and "P"	,, ,,	N	,,	,,	,,

Drive-pipe.—With special long threads, and patent couplings, is supplied in pieces 10 feet long, threaded so that ends of pipe butt together when screwed up. Common pipe may be used for drive-pipe where the depth is not too great, but it will not stand such severe usage as the special drive-pipe.

Table of sizes, etc., as under :—

Nominal inside diameter.	Actual inside diameter.	Outside diameter.	Diameter of Coupling.	Weight, per foot.	Threads to inch. American.	Threads to inch. English.
Inches.	Inches.	Inches.	Inches.	lbs.		
3	3·06	3·50	4 7/32	7·54	8	11
3½	3·56	4·00	4 11/16	9·00	8	11
4	4·02	4·50	5 9/32	10·66	8	11
4½	4·50	5·00	5 24/32	12·34	8	11
5	5·04	5·56	6 13/32	14·50	8	11
6	6·06	6·62	7 13/32	18·76	8	11
7	7·02	7·62	8 13/32	23·27	8	11
8	7·98	8·62	9 10/32	28·18	8	11

American pipe is threaded only 8 threads per inch. English pipe is threaded 11 threads per inch, and the finer threads enable the joint to be kept to maximum strength. English drive-pipe with thin steel sockets is made in the highest quality by James Russell & Sons, Stewarts, Spencers, and others.

APPENDIX.

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I.—DATA TO BE GIVEN WHEN MAKING INQUIRIES IN REGARD TO PURCHASE OF DIAMOND DRILLS.

1. Will the work be from surface or underground?
2. If underground, give dimensions or space available where the drill is to be used, especially in line of drill-rods.
3. What is the character of the surface or drift deposit overlying the rock, and what is its estimated depth?
4. What rocks enter into the formation?
5. Is the rock solid, or broken, and liable to cave?
6. What mineral or metal is sought?
7. What is the maximum depth of holes?
8. What is the total footage to be drilled?
9. Is compressed air, steam, or electricity the motive power?
10. Is there a supply of water close by? All details must be given in respect to this.

II.—EQUIPMENT TABLES FOR SULLIVAN DIAMOND CORE DRILLS.

The following equipment is furnished with the Sullivan drills, "A," "B," "C," "H," "N," and "P," *without extra charge*:—

Drill, on frame.
2 blank bits, ready to set.
200 feet of drill-rods, with couplings.
1 half-length of drill rod, with coupling.
1 10-feet core-barrel.
1 core-lifter (consisting of shell and lifter).
50 feet 4-ply water-hose, with connection for drill-rods.
12 feet 4-ply water-hose, with connection to connect drill and pump.
17 feet 4-ply suction-hose, with connection and strainer.
10 feet 7-ply steam-hose, with connection for drill (5-ply for "A," "C," and "H").
5 feet 2-ply drip-hose.
1 swivel steam connection for engine.
1 wire rope (wound on hoisting-drum), with hook.
    With "A," "C" and "H" drills, 75 feet of ½-inch rope; with "B" and "N," 100 feet of ⅝-inch rope; with "P" drill, 150 feet of ⅞-inch rope.
1 drive-chuck.
1 top-chuck.
1 safety-clamp.
1 sheave for hoisting-rods, with strap and hook.
1 lifting-bail, with clevis.
1 bail and bolt for sheave.

1 lifting-swivel or hoisting-plug, with coupling.
1 water-swivel, with coupling and elbow.
1 pressure gauge, for feed cylinder.
1 tool chest, with lock and key.
1 complete set of diamond-setting tools, consisting of—
    1 $3\frac{1}{4}$ jaw vice, with swivelled base and jaw.
    1 breast drill, with five bits, from $\frac{1}{8}$-inch to $\frac{1}{4}$-inch diameter.
    1 set of 12 setting chisels and punches.
    1 light hammer for diamond setting.
    1 pair each 6-in. dividers, inside and outside calipers.
    1 head for holding bits.
    1 lb. copper wire.
1 machinist's hammer.
1 screw-driver.
1 draw bolt for gears.
1 copper strainer and union.
1 6-inch adjustable level.
2 pairs pipe-tongs, adjustable 1 inch to 2 inch.
1 14-inch pipe-wrench.
2 12-inch monkey wrenches.
1 complete set of solid wrenches for engine, chuck, etc.
1 malleable hand oiler.
1 1-gallon oil-can.
1 leather-packing mould for hydraulic piston.
1 steel pin for packing box.
1 engine oil-cup, with valves.
2 recovering taps.
Rubber and hemp packing and waste.

All pipes and fittings necessary to connect drill pump and boiler.

The following extra equipment is necessary :—

Boiler, of suitable h.p., on wheels, complete with mountings, injector, flue-cleaner, pokers, etc.

1 duplex pump, of suitable proportions.
1,000 to 1,500 feet of drill-rods, with couplings.

144 extra blank bits.
12 bevel core-shells.
12 split core-lifters.
2 core-barrels.
2 cross chopping-bits.
2 pipe-clamps.
2 pairs chain-tongs.
2 recovering taps.
1 set friction plate and balls.
2 sets pipe stocks and dies.
1 set extra safety-clamp jaws.

The following equipment is furnished with the "E," "G," and "C" drills *without extra charge*:—

Drill, boxed with standards and braces.
2 blank bits, ready for setting.
195 feet of drill-rods and couplings, including five 1-foot rods.
1 20-inch core-barrel.
1 core-lifter shell, with two lifters.
17 feet of 1-inch 4-ply steam-hose.
17 feet of $\frac{3}{4}$-inch 2-ply water-hose.
7 feet of $\frac{1}{2}$-inch 2-ply water-hose.
1 water-swivel, with coupling.
1 lifting-swivel.
1 drive-chuck.
1 top chuck.
1 safety-clamp.
1 extra set of feed-gears.
1 extra friction spring.
1 pressure gauge.
1 tool chest, with lock and key.
1 complete set of diamond-setting tools, consisting of:—
    1 $\frac{3}{4}$-inch jaw vice, with swivelled base and jaw.
    1 breast-drill, with five bits, from $\frac{1}{8}$-inch to $\frac{1}{4}$-inch diameter.
    1 set of 12 setting chisels and punches.
    1 light hammer for diamond setting.

- 1 pair each 6-inch dividers, inside and outside calipers.
- 1 head for holding bits.
- 1 lb. copper wire.

1 machinist's hammer.
1 6-inch adjustable level.
1 pair pipe-tongs.
2 14-inch pipe-wrenches.
2 10-inch monkey wrenches.
1 complete set of solid wrenches for engine.
1 13-inch sheave-wheel, with strap and hook.
1 13-inch sheave-wheel.
1 malleable hand oiler.
1 $\frac{1}{2}$-gallon oil-can.
1 engine oil-cup.
2 recovering taps.
Rubber and hemp packing and waste.
Valves and fittings ready to connect to supply of steam or compressed air.

The equipment furnished with the "R" drill is the same as that supplied with the "E" and "G," and includes also motor and pump attached to drill-frame, carbon brushes switch, two fuse-boxes and extra fuses.

The following equipment is furnished with the "M" hand-power drill:—

Drill, boxed with standards.
2 blank bits, ready to set.
1 set of 12 chisels and punches, for setting diamonds.
1 head for holding bits whilst setting.
100 feet of drill-rods, with couplings.
1 lever hand pump.
1 10-foot core-barrel.
1 20-inch core-barrel.
1 core-shell and lifter.
12 feet of 1-inch 4-ply suction-hose.
10 feet of $\frac{1}{2}$-inch 2-ply water-hose.

1 water-swivel.
1 lifting-swivel.
1 coupling, drive-spindle to rods.
1 safety-clamp.
1 complete set feed-gear (three pairs).
1 tool box, with lock and key.
2 pairs pipe-tongs.
1 10-inch monkey wrench.
1 14-inch pipe-wrench.
1 complete set solid wrenches.
1 hand oil-can.
1 half-gallon oil-can.
1 copper strainer.
2 hand cranks.
1 13-inch sheave-wheel, with strap and hook.
1 15-inch pulley, for attaching power to crank-shaft.

Extra Equipment.—The extra equipment required with a drilling outfit depends on the nature of the work to be done; that is, the formation to be drilled, the depths to which it is required to penetrate, etc.; also the distance of the drilling sites from shops and supplies.

The nature of the formation, and depths of the holes, determines the amount of stand-pipe, casing, and extra rods and fittings necessary, whilst the distance from shops or supplies governs the amount of ordinary parts necessary to make the outfit independent in case of breakage.

An equipment for South Africa, for drilling up to 3,000 *feet,* should include the following extras other than those given in the general equipment tables :—

Stand-pipe.
Casing-pipe.
Casing-reamer.
Chopping-bits.
2 jacks, either the common screw or ratchet.
Rope, blocks, and chain.
Chain-tongs, for casing-pipe.

Drive-head, shoe, and drive-block.
Pipe-clamps for drive-pipe and casing.
Hand saw, axe, shovel, pick, sledge, auger, pipe-cutter.
Stocks and dies to cut pipe from ½ inch to 2 inches.
Gun-metal bull wheel.
Water-swivel.
Hoisting-plug.
Core-barrels.

In English practice it is usual to use hollow screw jackets, consisting of an outer stand with gun-metal square-threaded sleeve, in which works a hollow screw, the hole through the screw being large enough to pass freely over the drive-pipe to be withdrawn. The head is loose, with a single or double ring of balls, and allows easy rotation of the screw, which has a capstan head for long bars. The pipe is fitted with heavy bolted clamps, against which the screw-jack works, and which are shifted down the pipe with each successive stroke of the jack. The stroke is limited to 18 or 20 inches.

III.—SHIPPING WEIGHTS AND DIMENSIONS OF SULLIVAN DIAMOND DRILLS.

"P" DRILL.

Weight of drill, complete with swivel-head	5,000 lbs.
,, ,, frame	820 ,,
,, ,, equipment	2,900 ,,
Total weight, drill and equipment	8,720 ,,
In 12 boxes, occupying, with drill and frame, about	200 cub. ft.
Weight of swivel-head and drive-rod, when detached, about	1,100 lbs.
Weight of rods, boxed with couplings, per 100 feet	585 ,,
Weight of 25 h.p. boiler, on wheels	8,100 ,,
,, ,, 8 × 4 × 12 duplex pump	2,400 ,,

"N" DRILL.

Weight of drill, without swivel-head	1,950 lbs.
,, ,, swivel-head, boxed separately	625 ,,
,, ,, frame	690 ,,
,, ,, equipment	2,300 ,,
Total weight, drill and equipment	5,565 ,,
In 9 boxes, occupying, with drill and frame, about	134 cub. ft.
Weight of rods, boxed with couplings, per 100 feet	585 lbs.
Weight of 20 h.p. boiler, on wheels	7,250 ,,
,, ,, 6 × 3 × 7 duplex pump	1,070 ,,

"B" DRILL.

Weight of drill, without swivel-head	1,950 lbs.
„ „ swivel-head, boxed separately	530 „
„ „ frame	690 „
„ „ equipment	2,010 „
Total weight, drill and equipment	5,180 „
Packed in 9 boxes, occupying, with drill and frame, about	132 cub. ft.
Weight of extra rods, boxed with couplings, per 100 feet	450 lbs.
Weight of 15 h.p. boiler, on wheels	6,000 „
„ „ 6 × 3 × 7 duplex pump	1,070 „

"A" OR "C" DRILL.

Weight of drill, without swivel-head	1,060 lbs.
„ „ swivel-head, boxed separately	380 „
„ „ frame	440 „
„ „ equipment included in price	1,660 „
Total weight, drill and equipment	3,540 „
Packed in 9 boxes, occupying, with drill and frame, about	111 cub. ft.
Weight of extra rods, boxed with couplings, per 100 feet	370 lbs.
Weight of 12 h.p. boiler, on wheels	5,500 „
„ „ 6 × 3 × 7 duplex pump	1,070 „

"H" DRILL.

Weight of drill, without swivel-head	880 lbs.
„ „ swivel-head, boxed separately	360 „
„ „ frame	370 „
„ „ equipment	1,660 „
Total weight, drill and equipment	3,270 „
Packed in 9 boxes, occupying about	95 cub. ft.
Weight of extra rods, with couplings, per 100 feet	370 lbs.
Weight of 10 h.p. boiler, on wheels	5,200 „
„ „ 4½ × 2⅜ × 5 special pump	275 „

“S” Drill.

Weight of drill, complete	840 lbs.
,, ,, equipment	1,360 ,,
Total weight	2,200 ,,
Packed in 7 boxes, occupying about	60 cub. ft.
Weight of extra rods, boxed with couplings, per 100 feet	385 lbs.
Weight of 8 h.p. boiler, on wheels	4,650 ,,
,, ,, 4½ × 2⅜ × 5 special pump	275 ,,

“M” Drill.

Weight of drill, complete	280 lbs.
,, ,, equipment	800 ,,
Total weight	1,080 ,,
Packed in 5 boxes, occupying about	30 cub. ft.
Weight of extra rods, boxed with couplings, per 100 feet	385 lbs.

“E” or “G” Drill.

Weight of “E” or “G” Drill, complete	580 lbs.
,, ,, equipment	1,150 ,,
Total weight, drill and equipment	1,730 ,,
Packed in 9 boxes, occupying about	32 cub. ft.
Weight of extra rods, boxed with couplings, per 100 feet	385 lbs.
Weight of 8 h.p. boiler, on wheels	4,650 ,,
,, ,, 4½ × 2⅜ × 5 special pump	275 ,,

“R” Drill. (See Underground Prospection.)

Weight of drill, complete with pump and motor attached	1,250 lbs.
Weight of equipment	1,110 ,,
Total weight, drill and equipment	2,360 ,,
In 7 boxes, occupying with drill, crated, about	70 cub. ft.
Weight of rods, boxed with couplings, per 100 feet	385 lbs.

IV.—SPECIFICATION OF OUTFITS SUPPLIED WITH BULLOCK DRILLS.

CLASS B.

1 $1\frac{3}{8}$-inch bit, set with 8 diamonds.
1 $1\frac{3}{8}$-inch bit-holder.
1 $1\frac{3}{8}$-inch bit-blanks.
1 $1\frac{3}{8}$-inch core-lifter, and one extra ring.
1 $1\frac{3}{8}$-inch × 5 core-barrel.
1 20-inch core-barrel.
39 5-feet lengths (195 feet), $1\frac{5}{16}$ inches × 5 feet-standard drill-rods, with couplings, for underground work.
1 $1\frac{3}{8}$ inch × 10 feet core-barrel.
1 20-inch core-barrel.
19 10-feet lengths (190 feet), and 2 5-feet length-standard drill-rods, with couplings, for surface work.
1 $1\frac{5}{16}$-inch hoist-plug.
1 $1\frac{5}{16}$-inch combination water-joint and hoist-plug.
12 feet $\frac{1}{2}$-inch 4-ply water-hose, with nipples fixed.
1 pair No. 2 and 2 pairs No. 3 Brown's tongs.
2 12-inch monkey wrenches.
1 15-inch B and C pipe-wrench.
1 swivel-head wrench.
1 set of solid steel engine wrenches.
1 malleable oiler.
1 $\frac{1}{2}$-gallon oil-can.
1 globe valve, fitted to engine.
1 lubricator, fitted to engine.
1 No. 2 Smith's combination pipe-vice.
1 breast-drill.

6 twist-drills.

6 assorted files.

1 pair 4-inch dividers.

1 pair each 4-inch inside and outside calipers.

1 set (10) diamond setter's tools.

1 diamond setter's hammer.

1 machinist's hammer.

1 12-inch sheave-wheel (not furnished with underground drill).

75 feet $\frac{1}{8}$-inch steel rope, with swivel-hook (not furnished with underground drill).

1 fishing tap, for $1\frac{3}{8}$-inch core-barrel, and $1\frac{5}{16}$-inch rods.

1 $1\frac{5}{16}$-inch patent improved safety-clamp.

1 level, $\frac{1}{8}$ lb. drill engine packing, $\frac{1}{2}$ lb. hemp, 2 lbs. waste.

1 tool box, with lock and key.

STANDARD POWER OUTFIT.

CLASS B.

One Class "B" 3 × $1\frac{3}{4}$ × 3 duplex pump, with all discharge pipe and connections from pump to drill, weight, 130 lbs.

1 12-feet length $1\frac{1}{4}$-inch rubber suction-hose, fitted with foot-valve and strainer.

1 No. 2 8 h.p. locomotive boiler, fitted with inspirator, and all piping to connect boiler, pump and drill; boiler mounted on iron wheels, with wide tires.

Weight of boiler, on wheels . . .	4,970 lbs.
,, ,, ,, skids . . .	3,290 ,,
Extra drill-rods, with couplings, boxed, per 100 feet	350 ,,

CLASS C.

1 $1\frac{3}{4}$-inch bit, set with 8 diamonds (carbons).

50 $1\frac{3}{4}$-inch bit-blanks.

1 $1\frac{3}{4}$-inch bit-holder.

4 $1\frac{3}{4}$-inch patent core-lifter, complete with 4 extra rings.

3 $1\frac{3}{4}$ × $10\frac{1}{2}$-inch patent core-barrel, spirally grooved outside.

1,200 feet $1\frac{5}{8}$-inch × 10-feet drill-rods.
2 $1\frac{5}{8}$-inch water-joints, and 12 feet of $\frac{1}{2}$-inch hose.
1 each 12-inch and 18-inch Coe's wrenches.
1 pair No. 2 Brown's tongs.
2 pairs No. 3 Brown's tongs.
1 malleable oiler.
1 1-gallon wood-covered oil-can.
1 15-inch B and C combination pipe-wrench.
1 No. 12 breast-drill, and 6 twist drills.
1 pair each inside and outside calipers.
1 pair 4-inch spring dividers.
1 diamond setter's hammer, 1 machinist's hammer.
1 set (10) diamond setter's tools.
1 lb. copper wire and $\frac{1}{2}$ lb. Winan's packing.
2 flat and 2 Cape chisels.
1 axe, 1 saw, 1 sledge, 1 shovel.
75 feet $\frac{1}{2}$-inch steel wire rope, with hook and socket attached.
1 fishing tap for $1\frac{3}{4}$-inch core-barrel; 1 for $1\frac{5}{8}$-inch drill-rods.
2 $1\frac{5}{8}$-inch plain hoist-plugs.
2 $1\frac{5}{8}$-inch combined water-joint and hoisting-plug.
1 swivel-head wrench.
1 $1\frac{5}{8}$-inch improved safety-clamp (patent).
1 pair $1\frac{5}{8}$-inch safety-clamp jaws.
1 pair $1\frac{5}{8}$-inch drill chuck jaws.
3 each upper and lower core-barrel couplings.
1 No. 2 Smith combination pipe-vice.
1 12-inch special hoisting-sheave for derrick.
1 tool box, with lock and key.

Power Outfit.

1 $4\frac{1}{2}$-inch × $2\frac{3}{4}$-inch × 4-inch Worthington duplex pump, complete.
1 No. 3 portable boiler, locomotive style, mounted on broad tire wheels, complete with stack and the usual fittings and fixtures, including injector-pipe, ready for fire.
1 complete set of pipe, connecting boiler, pump and drill.

1 12-feet length 1½-inch wire-line hard rubber suction-hose, fitted with foot-valve and strainer.

1 30-feet derrick.

Class D.

1 2-inch bit, set with 8 carbons.

2 2-inch bit-blanks.

1 2-inch bit-holder.

1 2-inch patent core-lifter, complete with 1 extra ring.

1 2-inch × 8-feet patent core-barrel, spirally grooved outside.

200 feet 1⅞-inch × 8-feet short coupled drill-rods, including one 4-feet length.

1 1⅞-inch water-joint, and 12 feet by ¾-inch 3-ply steam-hose.

1 each 12-inch and 18-inch Coe's wrenches.

1 15 B and C combination pipe-wrench.

1 pair No. 2 Brown's tongs.

2 pairs No. 3 Brown's tongs.

1 pair No. 4 Brown's tongs.

1 malleable oiler ; 1 1-gallon wood-covered oil-can.

1 No. 12 breast-drill and 6 twist drills.

1 pair each 4-inch inside and outside calipers.

1 pair 4-inch spring dividers.

1 diamond setter's hammer.

1 set (10) diamond setter's tools.

1 machinist's hammer.

1 lb. No. 18 copper wire ; ½ lb. packing.

2 flat and 2 Cape chisels.

1 axe, 1 hand saw, 1 sledge, 1 shovel.

75 feet ⅝-inch steel wire rope, with hook and socket attached.

1 fishing tap for 2-inch core-barrel.

1 fishing tap for 1⅞-inch drill-rods.

1 1⅞-inch plain hoisting-plug.

1 1⅞-inch combined hoisting-plug and water-joint.

1 1⅞-inch patent improved safety clamp.

1 24-inch special hoisting-sheave for derrick.

1 No. 88½ Parker's combination pipe-vice.
1 tool box, with lock and key.

Power Outfit.

1 4½ × 2¾ × 4-inch Worthington duplex pump.

1 No. 4 12 h.p. portable boiler, mounted on broad tire wheels, fitted with injector, and all piping to boiler, drill and pump.

20 feet 1½-inch hard rubber suction hose, fitted with foot-valve and strainer.

Class B.

Shipping weights of the Beauty diamond drill, complete with the regular 1⅝-inch 200-feet outfit :—

Underground prospecting outfit :—

Beauty drill, mounted on columns, and complete with regular outfit	1,850 lbs.

Surface prospecting outfit :—

Beauty drill, mounted on bed-plate, and complete with regular outfit	1,900 lbs.
No. 2 8-h.p. boiler, mounted on wheels, and complete with fixtures	4,970 ,,
3 × 1¾ × 3-inch duplex pump, with suction-hose	175 ,,

Class D.

Shipping weights :—

Weight of drill, with regular outfit	4,600 lbs.
,, ,, pump and fittings	400 ,,
,, ,, 12 h.p. boiler and fittings . . .	5,600 ,,
Total shipping weight.	10,600 ,,

1⅞-inch drill-rods will average 5 lbs. per foot, boxed.

V.—PRICE LIST (IN DOLLARS) OF SPECIAL TOOLS AND SUPPLIES.

Bail and Clevis.

Size of rods	A	B	E	N	P
Price, each consisting of bail and clevis . .	$3.50	4.00	3.50	5.00	5.00

Bits: Shows bits set with diamonds.

Size	A	B	E	N
Diameter, inches	1¾	2	1½	2¾
Price per dozen . .	$15.00	15.00	12.00	21.00

Bits: Casing-bits for flush joint casing.

Size of casing, inches	E	2	2½	3	3½	4
Price, each .	2.50	3.00	4.00	4.75	5.25	5.50

Bits: Chopping-bits, with single-cutting edge. (In ordering give size of wash-pipe the bit is to be screwed into, or diameter of screw and number of threads per inch, as well as length of cutting edge of bit.)

Length of cutting edge, inches, 2¾, 3⅜, 3⅞, 4⅜, 4⅞, 5⅞, 7⅞.

Used inside drive pipe or casing of nominal inside diameter.

Inches	3	3½	4	4½	5	6	8
Price, each .	$5.75	6.50	7.00	7.50	8.00	10.00	15.00

Bits: Chopping-bits, with two crossed cutting edges, threaded for drill-rods.

Size of drill-rods	A	B	E	N
Length, cutting edge, inches	1¾	2	1½	2¾
Price, each	$6.25	7.50	5.00	10.00

Bushing—from drill rods to casing. Any size rods.

Diameter of casing	E	2	2½	3	3½	4	4½
Price, each . .	$3.00	3.00	3.5	4.0	4.5	5.0	5.5

Casing Thread Protectors, for flush joint casings.

Size of pipe	E	2	2½	3	3½	4
Price per pair . .	$.50	.50	.50	.60	.70	.80

Chucks: Drive-chucks.

Size of drill	A, C, H	B	E, R, S	N	P
Price, complete .	$15.60	21.90	15.60	35.00	45.00
Extra Jaws . .	3.12	3.12	3.12	5.62	7.50

Clamps.—Safety-clamps.

Size of drill	A, C, H	B	E, R, S	M	N	P
Price complete, each . .	$17.00	50.00	17.00	17.00	53.00	60.00
Extra Jaws, stationary .	3.12	7.50	3.12	3.12	7.50	9.25
Extra Jaws, swinging .	5.00	20.00	5.00	5.00	20.00	25.00

Clamps.—Pipe-clamps.

Price, with bolts and nuts.

Size of pipe, inches	2	2½	3	3½	4	4½	5	5½	6
	$4.0	4.5	6.0	6.0	8.0	8.0	8.5	8.5	9.0

Clevis.—See *Bail and Clevis.*

Core-barrels.

Size of bit	A	B	E	N
Price, 10 feet length .	$14.00	20.00	12.50	37.50
„ 5 „ „			10.00	
„ 20 „ „	8.00	10.00	7.00	

Other sizes in stock or to order.

Core-lifters.—Cossette, with loose jaw and steel spring.

Size	A	B	N
Price, each . .	$3.80	3.80	6.25
Extra Jaws, each . .	.26	.26	.26
Extra Springs, each . .	.06	.06	.06

Core-lifters (spring steel) *for "E" fittings.* Specially designed for small "E" cores. Price, each, $1.00.

Core-lifters.—Taper split-ring Core-lifters.

Size	A	B	E	N
Straight Shell, for cossette and upright core-lifters, each	$3.25	3.25	3.25	5.00
Bevel Shell, for taper split-ring core-lifters, each	5.00	5.00	5.00	5.00

Drill-rods, with couplings.

Size	A	D	E	E	N
Outside diameter, inches	$1\frac{5}{8}$	$1\frac{15}{16}$	$1\frac{5}{16}$	$1\frac{5}{16}$	$2\frac{3}{8}$
Length in feet	10	10	5	10	10
Weight per 100 feet, boxed	370	450	385	385	585
Price per 100 feet .	$69.50	75.50	72.50	60.00	95.00
Extra couplings, each .	1.25	1.25	1.00	1.00	1.50

NOTE.—A rods are used with "A," "C" and "H" drills; B rods are used with "B" drills; E rods are used with "E," "G," "M," "R" and "S" drills; N rods are used with "N" and "P" drills.

Drive-blocks, for driving stand-pipe. Cast-iron, with lifting clevis and guide bolts. Price $17.00.

Drive-head and Shoes. Price, head or shoe:—

Size pipe, inches	2	2½	3	3½	4	4½	5	6	8
	$5.0	6.0	7.0	8.0	10.0	11.0	12.0	15.0	20.0

Frame for "E" Drill surface work.—This is not necessary for the successful operation of the drill, but as the "E" was designed for work of underground prospecting, it is found more convenient to use the frame where much surface work has to be done. Weight, about 250 lbs.

Price of frame, with hand hoist complete, also with clamps and bolts for holding drill to frame and frame to floor, $70.00.

Hoist for "M" Drill.

Price complete, with hook and rope, $35.00.

Hoisting-plugs, or Lifting-swivels.

Size of rods	A	D	E	N
Price, each . .	$8.00	8.00	6.00	12.00

Horse Powers.—By means of a "horse power" the "M" drill can be used to a depth of 400 or 500 feet. Price of horse power, including jack and belt, and connections, $50.00.

Lifting-swivels.—See *Hoisting-plugs.*

Reamers.—

Size of casing to be inserted	E or 2	2½	3	3½	4
Long Reamers, complete	$22.00	24.00	28.00	33.00	38.00
Extra Faces, each .	2.50	2.50	3.00	3.50	4.00
Short Reamers, complete	6.25	8.75	9.75	11.00	11.50
Extra Faces, each .	3.00	4.00	5.00	5.5	6.00

Besides the above, other styles, adapted for use in special cases, are obtainable. In ordering be sure to specify size of guide, size and kind of casing to be inserted, and size of drill-rods to be used with reamer.

Setting-blocks, for holding blank bits while setting the diamonds.

Size	A	B	E	N
Price, each .	$1.25	1.25	1.25	1.25

Sheave-wheels, with strap and hook.

Size of drill	A, C & H	B	E, M, R, S	N	P
Diam. of sheave, ins.	24	36	13	36	
Price complete	$10.25	17.50	7.50	17.50	30.00

Taps. (Rod-recovering taps, made of special tool steel, and properly tempered. In ordering taps, state size of rods or casing by which the tap is to be lowered; also whether the right- or left-hand tap is required.)

Taper Taps, right or left hand. Size rods	A	D	E	N
Price, each	$13.00	13.00	11.00	17.00
Coupling Taps, right or left hand.				
Price, each	$5.00	6.00	4.00	8.00
Hollow Taps, right or left hand.				
Price, each	$11.00	11.00	10.00	12.00

Casing-recovering Taps—Taper. (Same as *Taper Rod-recovering Taps.*)

Size casing, right or left hand, ins.	2	2½	3	3½	4
Price, each . . .	$15.00	20.00	25.00	30.00	35.00

Water-swivels, Common.

Size of rods	A	D	E	N
Price, each	$10.00	12.00	8.00	—
Water-swivels, with friction ball bearings . .	16.00	20.00	—	40.00

PRINTED BY H. VIRTUE AND COMPANY LIMITED, CITY ROAD, LONDON.