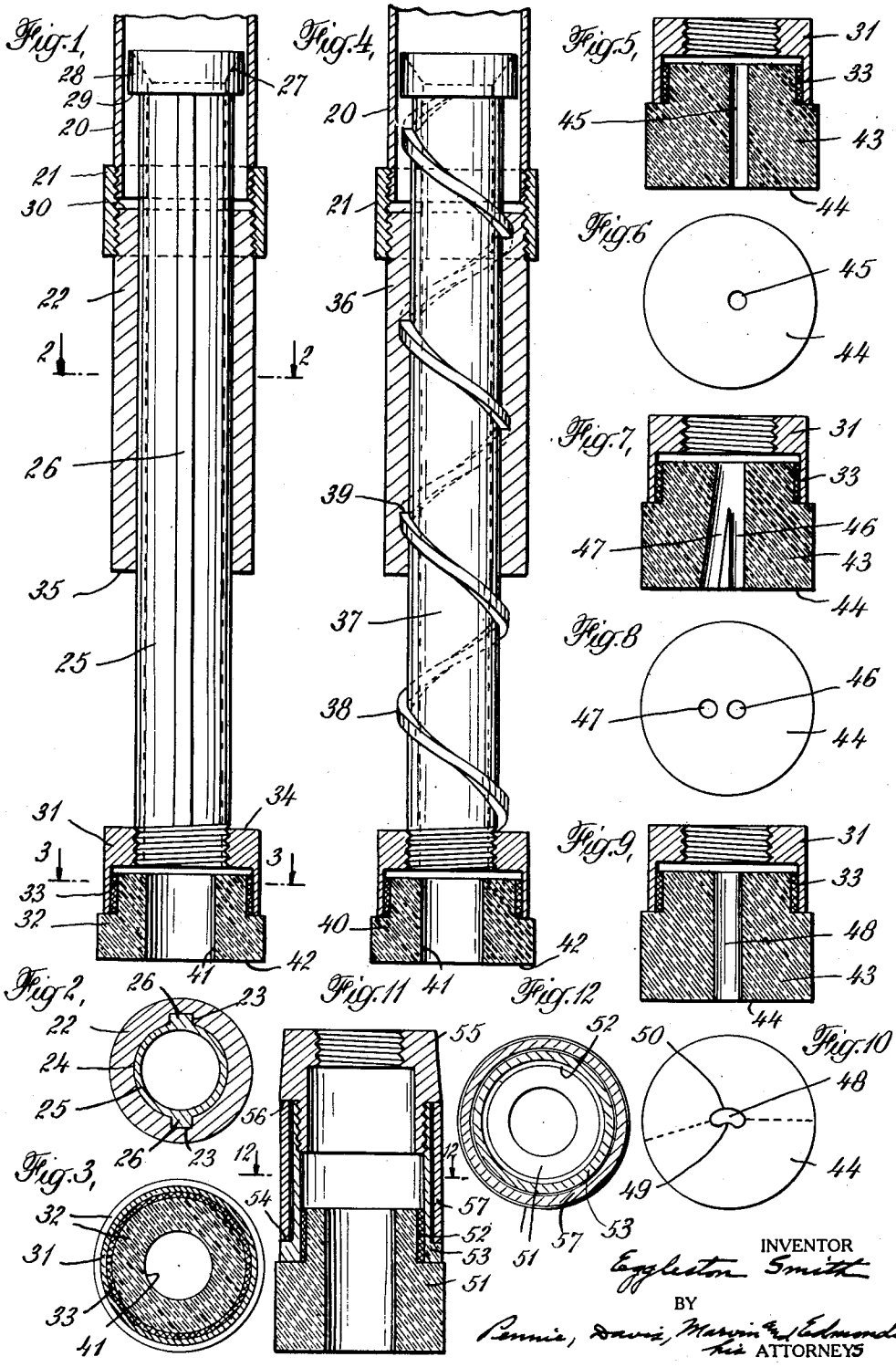
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WELL DRILLING APPARATUS

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WELL-DRILLING APPARATUS.

Application filed May 10, 1924. Serial No. 712,197.

This invention relates to well drilling apparatus and especially to well drilling apparatus of the type in which the cutting is done by the rotation of a drilling tool or bit; and, more particularly, the invention relates to well drilling apparatus employing a drilling tool having a cutting surface of abrasive material. The invention has for its object the provision of an improved well drilling apparatus.

The majority of the drilling tools or bits now used in drilling holes in the earth, as, for example, when boring for oil, gas, water, or minerals. are constructed of steel, or of a steel head studded with diamonds. The steel bits are effective in soft formations, but on account of the hardness of many of the rocks encountered in drilling, they wear so rapidly, even when constructed of the best materials and in accordance with the most modern practice, as to necessitate frequent and expensive renewals. In addition, in most drilling operations it is important that the material being drilled through be cut by the drilling tool directly into small fragments which are fine enough to be immediately carried to the surface of the ground by the drilling fluid. The steel bits now used with the rotational systems tend to cut the softer materials into coarser fragments than the flushing water can carry away.

The use of diamonds in the drilling industry is well established, but is extremely expensive. Drilling bits of about one and one-half inches in diameter are usually provided with six two-carat diamonds; those of about two and one-half inches with eight two-and-one-half-carat diamonds; and all larger sizes, up to about eight inches in diameter, with ten two-and-one-half-carat diamonds. The present cost of these bits set with diamonds ranges from $1500 for the smallest bit to $4000 for the largest bit. The initial cost of these bits, the cost of machinery to protect the diamonds, and the cost of operation, make the use of such bits in large holes prohibitive. Moreover, the results obtained in drilling holes with these bits are far from satisfactory.

The use of drilling tools or bits constructed of abrasive material, such as carborundum, has previously been suggested, but, as far as the present applicant is aware, they have not been successful and have not come into any extensive use. In well drilling, the operator is stationed at the surface of the ground and the great majority of the drilling work must, of necessity, be done at several hundred, or even several thousand, feet below the surface. In employing the abrasive bit it has heretofore been mounted on the end of the drive pipe which extends down the depth of the hole, and is rotated by suitable mechanism at the surface. The weight of this pipe becomes enormous as the hole increases in depth, and it is a practical impossibility for an operator at the surface to properly control his derrick so as to apply the right feeding pressure to the bit.

I have discovered that when an abrasive bit is operated in combination with a device so constructed as to regulate or limit the feeding pressure on the cutting surface of the abrasive, preferably to a relatively small amount per square inch, the abrasive bit becomes the most economical, efficient, and rapid well drilling bit of which I am aware.

In carrying out the invention, a drilling bit constructed entirely of abrasive material, or at least having a cutting surface of abrasive material, is connected with any suitable driving means by a positive weight limiting device which allows a predetermined weight to exert the feeding pressure upon the bit under all conditions of operation. The driving means employed may, for example, be similar to that shown and described in my co-pending application, Serial No. 637,761, filed May 9, 1923, in which a rotary cutting tool is rotated in contact with the bottom of the hole by means of a spiral slot and ratchet mechanism which is actuated by the reciprocation of a flexible cable extending from the vicinity of the bottom of the hole to the surface of the ground. This type of tool driving apparatus includes mechanism which positively limits the weight or feeding pressure exerted upon the tool.

In those systems of drilling where the tool is rotated by a drill stem or drive pipe which is driven by a rotating table at the surface and extends to the bottom of the hole, I employ a pressure limiting device for connecting the end of the drill pipe with the abrasive bit. This device consists of two members movable longitudinally relative to each other but provided with means for causing one of these members upon

which the tool is mounted to be positively rotated by the other member which is attached to the drive pipe. The means for imparting the rotation between these members comprises preferably one or more coacting ribs and grooves. These ribs and grooves may be parallel to the longitudinal axis of the device, thus making an angle of 0° therewith, or they may be of spiral shape, making a greater angle with the longitudinal axis. In the latter case relative longitudinal motion of the two members occurs which tends to reduce the feeding pressure upon the bit. Such a spiral connecting device is described in my co-pending application, Serial No. 681,032, filed December 17, 1923.

Further relating to the carrying out of my invention, I have found that the most effective and rapid cutting is achieved when the entire cutting surface of the abrasive bit is uniform and continuous, and is maintained in constant contact with the material to be cut, the contacting surfaces of the cutter and the material being continuously supplied with a film of water under suitable pressure so as to scour the abrading points of the cutting surface and immediately carry away the abraded particles, thus effectively preventing the "glazing" of the surface of the cutter. By this I mean that the cutting face of the bit is continuous and not provided with radial or other teeth to increase the pressure per square inch and provide channels between the teeth for the passage of the flushing water. The cutting face of the abrasive bit may, however, be flat, convex, or concave.

For drilling holes where it is desirable to leave a core which may be recovered to obtain information as to the character of the rocks drilled through, I employ a bit of abrasive material which is annular in form, the flushing water passing downwardly between the core and the inside wall of the bit. Where the rocks are known and easily drilled through it is not necessary to delay in order to recover cores and it is desirable to employ a bit which will drill a complete hole without leaving a core. In this second type of bit, I construct, in accordance with my invention, a suitable passageway for the flushing water longitudinally of the bit and so disposed with respect to the axis of the bit as to conduct the flushing water to substantially the entire area of the cutting face and yet permit the tool to cut a complete hole.

In drilling holes with abrasive bits there are certain conditions which tend to cause the deviation of the hole from a straight line. In order to reduce this tendency I place on the stem just above the bit a sleeve of non-abrasive material which is rotatable upon the stem and which, when deviation begins, is engaged by the walls of the hole. This engagement stops the rotation of the sleeve and the sleeve provides a bearing in which the bit holder can freely turn without tendency to scale off the walls of the hole.

In the accompanying drawings I have shown, merely by way of example, however, certain embodiments of my invention. In these drawings

Fig. 1 is a view in longitudinal section through my improved abrasive bit and feeding pressure limiting device provided with a pair of longitudinal ribs and grooves;

Fig. 2 is a view in transverse section taken on the line 2—2 of Fig. 1;

Fig. 3 is a similar view taken on line 3—3 of Fig. 1;

Fig. 4 is a view in longitudinal section of the improved abrasive bit in combination with a feeding pressure limiting device employing a spiral rib and groove as described in my co-pending application, Serial No. 681,032;

Figs. 5 and 6 are respectively a longitudinal section and a bottom view of the improved abrasive bit for drilling a complete circular hole and provided with a single eccentric water course;

Figs. 7 and 8 are similar views of an abrasive bit provided with a modified arrangement of water courses;

Figs. 9 and 10 are also views similar to Figs. 5 and 6 respectively, of an abrasive bit with a still further modified form of water course;

Fig. 11 is a view in longitudinal section of an abrasive bit and stem adjacent thereto provided with a loosely mounted sleeve for preventing the tendency of the hole to deviate from a straight line; and

Fig. 12 is a view in transverse section taken on the line 12—12 of Fig. 11.

In drilling with my improved apparatus the usual drive pipe is supported at the surface of the ground against longitudinal motion by means of a derrick and is rotated by a suitable rotating table on the derrick floor. By means of this derrick the drive pipe can be raised or lowered as desired, and a core catching device may be lowered into the hole on the end of a cable to take out the cores. The lower end 20 of the drive pipe is connected by means of the collar 21, provided with the ordinary threaded joints, to a driving sleeve 22 of the weight or feeding pressure limiting device. The driving sleeve 22 is provided on its inner surface with grooves 23 which are parallel to the axis of the sleeve and therefore form an angle of 0° therewith.

The remainder of the inner surface 24 of the driving sleeve is cylindrical. A cylindrical driven member 25, which is preferably hollow so as to reduce weight and also to provide a space for the reception of the core,

fits within the driving sleeve 22 and is provided with one or more ribs 26 which fit into and co-act with the longitudinal grooves 23. The upper end of the driven member or bit holder 25 is coned, as shown at 27, to facilitate the entrance of core catching devices.

The driven member 25 has a head 28 at its upper end, the lower shoulder 29 of which contacts with the top 30 of the driving sleeve 22 to prevent the driven member from dropping out of the sleeve when raising and lowering the apparatus. The lower end of the driven member is threaded to fit the bit mounting 31. This bit mounting consists of a steel shell to which the abrasive bit or cutter 32 is secured by means of babbitt or lead 33. The bit mounting is provided with a shoulder 34 which contacts with the lower end 35 of the driving sleeve when the device is collapsed.

The bit 32, as well as the bits to be described below, may be made of various abrasive materials, such as carbide of silicon (carborundum crystolon), aluminum oxide (aloxite, alundum), emory, diamond dust, or other well-known abrasives bound together with appropriate binders such, for example, as clay, rubber, shellac, bakelite, etc. The "grit" or size of abrasive particles used in the abrasive bits is chosen to a certain extent with respect to the hardness of the material to be drilled through. Thus, a small grit cutter is not as effective in cutting relative soft material, such as relatively soft rock, as a coarse grit cutter, because of the tendency to become glazed, that is, filled with abraded material between the cutting points. I prefer, however, to employ a drilling bit molded of carborundum having a particle size approximately equivalent to No. 12 grit, using rubber as the binding agent, as my investigations have shown that the bit so constructed, when used in combination with the feeding pressure limiting mechanism, is particularly effective in cutting material of widely different degrees of hardness.

In the operation of the apparatus just described the drilling tool is lowered into the hole until the bottom of the abrasive bit 32 rests upon the bottom of the hole, and the weight limiting device is partially collapsed so that shoulder 35 of the driving sleeve approaches shoulder 34 of the bit mounting. It is important, however, when the weight of the pipe 20 is large, as in the case of a deep hole, that these shoulders be not allowed to come in contact with each other, for this would place a large portion at least of the weight of the entire drive pipe upon the abrasive cutter 32 with probable resulting injury to the cutter. With the weight limiting device in partially collapsed condition, the drive pipe is rotated by means of the rotating table at the surface, and this rotation is imparted to the bit 32 through the co-acting grooves 23 and ribs 26.

The pressure exerted upon the bit in holding its cutting surfaces in contact with the bottom of the hole, is determined entirely by the weight of the bit itself, the bit mounting, and the driven member 25, minus whatever friction exists between the co-acting surfaces of the parts 22 and 25. The pressure applied to the bit, therefore, is accurately predetermined and unvariable. The pressure per square inch upon the cutting face of the tool 32 which gives the maximum rate of cutting in a given material may be determined by investigation, and the weight applied to the tool proportioned to exert this pressure. For example, the driven member 25 may be lengthened or shortened, or an additional weight may be added above the head 28, or an additional length of driving rod inserted between the end of the member 25 and the tool mounting 31. The lengthening of the tool mounting itself, or the introduction of a core barrel between the bit and member 25 will also serve to increase the constant weight upon the bit.

Referring now to Fig. 4 of the accompanying drawings, there is here shown a modification of the weight limiting and feeding pressure regulating device described in my co-pending application, Serial No. 681,032. In this modified apparatus the driving sleeve 36 is attached to the lower end 20 of the drive pipe which is supported from the surface of the ground against longitudinal motion and is rotated as before. The driven member 37 is movable longitudinally in driving member 36, is free to descend as the well is drilled, is rotated by pipe 20 by means of a co-acting helical rib 38 on member 37 and groove 39 in member 36, and is free to rotate within the driven member as controlled by the rib and groove. The angle which the helical rib and groove makes with the longitudinal axis of the driven member is not mentioned in my application above referred to, and it may vary from a relatively small angle to an angle somewhat less than 90°. In the device illustrated in Figs. 1 and 2 of the present application, this angle is 0°. In Fig. 4, this angle is intermediate between 0° and 90°. In using the feeding pressure regulating apparatus shown in Fig. 4, the feeding pressure applied to the abrasive bit 40, determined principally by the weight of the driven member 37 as in the case of the apparatus of Fig. 1, is reduced somewhat by the turning moment applied to the driven member through the spiral rib and groove. Thus, the feeding pressure is opposed by a variable force, the value of which depends upon the resistance to rotation encountered by the drilling bit 40. In other respects, however, the operation of the apparatus

shown in Fig. 4 is the same as that shown in Fig. 1.

The drilling bits 32 and 40 previously described are provided with relatively large circular longitudinal openings 41 leaving the bits with annular cutting faces 42 and allowing cores to be formed which project up into the hollow driven members 25 and 37 respectively. The annular faces 42 are uniform without radial teeth or channels, but they may be either flat, convex, or concave. When these bits are operated as above described, flushing water is forced down the interior of drive pipe 20, through the hollow weight limiting apparatus, and is supplied through the passage 41 to the contacting surfaces, that is, the cutting face 42 and the material being drilled. After issuing from between the contacting surfaces, the flushing water returns to the surface of the ground through the annular channel formed between the walls of the hole and the outside of the drive pipe 20. Inasmuch as there is always some unavoidable lateral motion of the drilling bit, the interior surface of the passage 41, which, as will be noted, is of abrasive material, cuts away enough of the walls of the core to provide adequate space for the flushing water between the core and the interior of the bit and the weight limiting device.

It is important that the cutting face 42 be uniform and continuous, that is, it is not provided with cutting teeth or radial channels leading from the passage 41 across the cutting face to the exterior of the bit. The cutting face, moreover, is kept in constant contact with the material to be cut and the flushing water is constantly supplied to the cutting surfaces. Because of the uniform or continuous surface of the cutting face 42, the flushing water is forced to spread out between the surface of the cutter and the material being cut in a thin film which scours every portion of the face of the cutter and removes all particles of abraded material which may attempt to lodge in the spaces between the cutting points formed by the abrasive particles in the cutting face. This scouring action of the flushing water under appropriate pressure maintains the cutting face in constantly clean condition and entirely prevents the glazing of the cutting face, which otherwise would retard or entirely prevent the advance of the tool through the material being drilled.

In Figs. 5 to 10, inclusive, of the accompanying drawings, various forms of abrasive bits intended for cutting entire or complete holes without leaving cores are shown. These bits are in general similar to bits 32 and 40 previously described, that is, they comprise a body 43 of abrasive material which is secured into a bit mounting 31 by means of babbitt or lead 33. Also, the cutting faces 44 of each of these bits are uniform and continuous, and may be made either flat, convex, or concave. Inasmuch as relatively little water is required for the operation of my improved abrasive bit, water courses of relatively small cross section may be provided to carry the water through the body of abrasive material to the cutting face. These passageways, however, are so disposed with respect to the axis of the bit as to leave no portion of the material in contact with the end of the bit which is not subjected to a relatively large cutting action some time during each rotation of the bit. The water courses are also arranged so that the paths taken by the water across the face of the bit in various directions will be as nearly the same length as possible so as to cause a substantially uniform distribution of water over the entire cutting face.

In Figs. 5 and 6 the water course comprises a single circular hole 45 which is slightly eccentric to the axis of the bit and preferably tangent to this axis, as indicated in Fig. 6. Thus, the material at the center of the bit will be entirely cut away so that no core will be left and yet the flushing water passing downwardly through hole 45 will find paths of approximately equal radial lengths from the hole 45 across the face 44 to the outside boundary of the bit.

In Figs. 7 and 8 a pair of holes 46 and 47 are provided. Hole 46 is placed similarly to hole 45 above mentioned, and hole 47 is molded on the opposite side of the bit axis to that of hole 46 and at a somewhat greater distance from the center. These two water courses, however, may be symmetrically placed with respect to the axis if it is desired.

In Figs. 9 and 10 a passageway 48 of a particular shape is shown. The longest dimensions of this passageway are bounded by the arcs of two circles 49 and 50 respectively, circle 49 preferably passing through the axis of the bit. By making the water course of this shape, the several radial paths from the water course to the outside of the bit approximately between the larger angle formed between the radial dotted lines in Fig. 10, will be substantially equal. Also, the radial paths between the smaller angle formed between these dotted lines will be substantially equal, but of a slightly greater length than the group of paths included between the larger angle.

By constructing the bits with water courses as just described, the film of water is kept substantially uniform over the entire face of the bit and the wear on the various portions of the face will be even.

Referring now to Figs. 11 and 12, which illustrate a device for use in connection with an abrasive bit to reduce the tendency to

deviate from a straight line as it cuts its way through the material, a core cutting bit 51 is shown secured by means of the babbitt 52 within a bit mounting 53. The shank of the bit mounting 53 is made considerably longer than that of the mounting previously described, and is reduced in diameter so as to form a lower shoulder 54. The upper end of the shank is threaded internally to receive a cap piece 55 provided with appropriate threads for securing the tool to the end of a feeding pressure limiting or regulating device such as shown, for example, in Figs. 1 and 4. The cap piece 55 is provided with a shoulder 56 and between this shoulder and shoulder 54, upon the shank of the bit mounting, there is placed a collar 57 of non-abrasive material, such as metal, and somewhat smaller in diameter than the diameter of the bit 51. The collar 57 makes a loose fit with the shank of the cutter mounting so as to be easily rotatable with respect thereto. The length of sleeve 57 has been shown as slightly greater than the length of the bit 51, but may be a much greater length if desired.

When a bit of this type is operating in a hole, certain conditions may cause the cutter 51 to have a tendency to cut into the side of a hole, or "underream." A slight underreaming of the hole will bring the loosely fitting collar 57 into engagement with the wall of the hole just above where the underreaming commenced, and this engagement will hold the collar stationary so that there is no further tendency of the tool, or the tool stem, or shank, to scale off the walls of the hole. The collar 57, because of its loose fit upon the bit mounting, will form an excellent bearing in which the shank of the tool may rotate, and this bearing is well lubricated by the muddy water in the hole. Thus, even with a relatively short sleeve such as the one illustrated, the tendency of the hole to deviate from the straight line will be materially reduced.

I have conducted relatively extensive investigations for the purpose of studying the operating characteristics of my improved well drilling apparatus as above described. In order to determine the rate of cutting obtainable with this type of drilling apparatus, an abrasive bit was operated with an automatic bit feed, such as illustrated in Fig. 4, driven by a variable speed motor. An abrasive bit, such as shown in Fig. 4, having the form of a hollow cylinder with a flat annular end which contacted with the material to be cut was mounted upon the automatic bit feed and supplied with water under a pressure of about eight pounds per square inch. It was found that the rate of cutting in material of uniform hardness was directly proportional to the pressure per square inch on the cutter, and was directly proportional to the number of revolutions of the cutter. A pressure of forty pounds per square inch with a given number of revolutions per minute produced twice the cutting that a pressure of twenty pounds per square inch produced at the same rotational speed. Likewise, a pressure of twenty pounds per square inch with three hundred revolutions per minute produced twice the cutting that was obtained at the same pressure with only one hundred and fifty revolutions per minute. Likewise, a pressure of twenty pounds per square inch produced the same cutting in three hundred revolutions, independent of whether the rate of speed was three hundred, one hundred and fifty, or fifty revolutions per minute. From these investigations it was possible to plot curves from which the rate of cutting under various conditions of bit pressure and rotational speed could be predicted. I found that the rates of cutting produced were remarkably greater than any rate of cutting that has ever been obtained with steel or diamond cutters, or any other cutter of which I am aware.

For the purpose of determining whether the cutting of radial or other teeth in the working face of the abrasive bit would increase the rapidity of cutting, teeth were cut in the face of the bit having one-half the contacting area of the face, and these teeth were later reduced to one-quarter of the contacting area. The reduction of the contacting area in the first case caused the pressure per square inch on the cutter to be doubled, and produced greater penetration of the abrasive points, but the resultant rate of cutting of an entire hole of given depth was less than with a bit having a uniform face. The reduction of area in the second case caused the pressure per square inch to be quadrupled, and the rate of cutting was still further reduced. In both of these cases, the drilling fluid passed through the channels between the teeth. Its scouring action on the abrasive working surface was eliminated, thus causing the abrasive points on the teeth to become clogged and to cut less effectively.

My investigations conclusively show that the highest rate of cutting is obtained when the entire cutting face of the abrasive bit is uniform and in constant contact with the material to be cut, or, in other words, when a plain-faced cutter, having no teeth and no channels for the drilling fluid, is used. Under these conditions each abrasive point is kept continuously at work and no portion of the abrading surface is left idle. The circulation of the water under the cutting face from the inside to the outside of the hole is confined to a thin circular jet which serves to scour away all material immediately after

it is abraded, and which keeps the entire bit clean and therefore in its most effective cutting condition.

Further investigations were conducted with the drilling of blocks of all degrees of hardness encountered in the drilling of wells, which showed that the improved drilling apparatus is particularly effective and that the amount of power required to operate the apparatus is remarkably small, being quite in contrast to the power required to operate the most efficient well drilling apparatus which is at present available.

The use of diamonds in well drilling has been mentioned above. The actual cutting of the holes in diamond drilling is done by from six to ten small cutting or abrasive points which necessarily comprise a relatively small percentage of the total area of the bit—probably less than 5% for the small bits and less than 1% for the large ones. With my improved abrasive drilling bit, however, a relatively large number of abrading points are scattered uniformly over the end of the bit utilizing the entire contact surface as a cutting surface. Abrasive bits, furthermore, are self-sharpening; that is, when each abrasive point wears down, the binder is torn out and a new abrasive point is exposed, so that the cutting qualities are not diminished by wear.

While I have given, in the course of this description, certain explanations which I now believe may account for the particularly effective results obtainable with my improved well drilling bit and apparatus, it is to be understood that these are purely explanatory. I do not wish to be limited to any particular theory or explanation of the results attained.

I claim:

1. In a well drilling apparatus the combination of an abrasive bit, driving means for rotating the bit at the bottom of a hole, and means for connecting the bit with the driving means so as to rotate the bit and at the same time allow longitudinal movement thereof with respect to the driving means so that the bit is free to descend under a predetermined feeding pressure as the well is drilled.

2. In a well drilling apparatus the combination of an abrasive bit, driving means for rotating the bit at the bottom of a hole, and a connecting device for attaching the bit to the driving means for imparting positive rotation to the bit and permitting vertical movement thereof with respect to the driving means so as to allow the feeding pressure upon the bit to be independent of the weight of the driving means.

3. In a well drilling apparatus the combination of an abrasive bit, a drive pipe for rotating the bit at the bottom of a hole, and a positive weight limiting connection between the bit and the end of the drive pipe comprising, driving and driven members vertically movable one with respect to the other, but interconnected with one another so that the driven member positively rotates with the driving member.

4. In a well drilling apparatus the combination of an abrasive bit, a drive pipe for rotating the bit at the bottom of a hole, and a positive weight limiting device for connecting the bit with the end of the drive pipe comprising, a driving member having a cylindrical longitudinal opening adapted to receive therewithin a cylindrical driven member, said members being provided respectively with a coacting rib and groove whereby the driven member is positively rotated but is permitted to move vertically with respect to the driving member.

5. In a well drilling apparatus the combination of an abrasive bit, driving means for rotating the bit at the bottom of a hole, means for applying a predetermined feeding pressure to the bit, and means for transmitting a rotational force between the driving means and the bit and preventing the transmission of a longitudinal force therebetween.

In testimony whereof I affix my signature.

EGGLESTON SMITH.