

April 9, 1929.

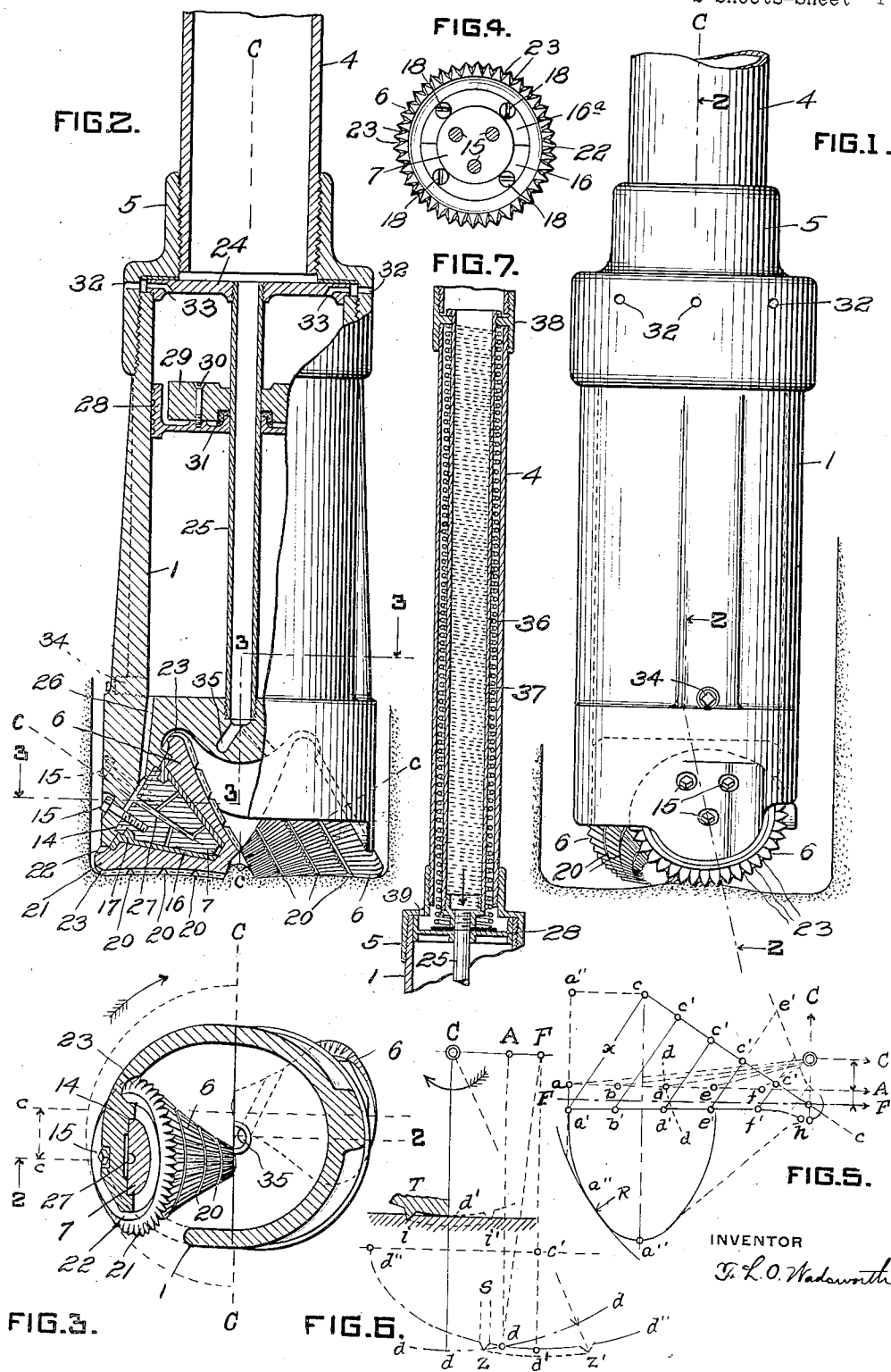
F. L. O. WADSWORTH

1,708,288

ROTARY BORING TOOL

Filed Feb. 3, 1921

2 Sheets-Sheet 1



INVENTOR
F. L. O. Wadsworth

UNITED STATES PATENT OFFICE.

FRANK L. O. WADSWORTH, OF PITTSBURGH, PENNSYLVANIA.

ROTARY BORING TOOL.

Application filed February 3, 1921. Serial No. 442,333.

My invention relates particularly to that type of rotary boring tools that are equipped with roller bit cutters and are designed to bore deep holes of relatively small diameter in rock and other hard formations. Oil wells are now frequently drilled to depths of four or five thousand feet; and in order that rotary tools of the character above described may be safely and efficiently operated at such depths it is necessary that they should possess certain well marked features of structure and of operation. For example: They should be of very strong and rugged construction—in order that they may successfully withstand the enormous stresses to which they are frequently subjected, both by the static pressure of the excessively long drill stems, and by the kinetic twisting and whipping strains of the very heavy and rapidly rotating parts. They must consist of relatively few members that are securely fastened together—in order to diminish, as far as possible, the danger of accidental loss of some part of the metal structure at the bottom of a deep bore hole with the consequent interruption, and possible prevention, of further drilling operations. They must be provided with cutter elements of such character as will permit of long continued periods of effective boring action—in order to diminish, as far as is practicable, the loss of time involved in “pulling” the long line of drill stem for the purpose of renewing the said elements. The design and arrangement of the revolving cutters or “roller bits” must be such as will enable them to retain their original cutting form as they wear down, and thus substantially maintain the desired diameter or “gauge” of the hole as the drilling proceeds—in order to eliminate the necessity of slow and expensive “reaming” operations, and also avoid the possibility of the “wedging” and twisting off of the rotating cutter head.

The object of this invention is to produce a rotary boring tool which will present all of the essential characteristics of construction that have been above enumerated; and which will also possess certain other desirable features of structure and functional performance that can be best explained in connection with the following exemplary embodiments, of my present improvements.

In the drawings of these illustrative constructions—which are more or less diagrammatic in character—Figs. 1 to 6 inclusive

depict one form or species of a roller bit drill mechanism, which presents some of the characteristic features of my invention; and Figs. 7 to 12 inclusive show other forms or species of rotary boring tool, which also embodies these and other general features of structure and functional performance. Considered more in detail, Fig. 1 is a side elevation of the first form of drill construction; Fig. 2 is a second elevation—partly in section on the bent plane 2—2 of Fig. 1; Fig. 3 is a sectional plan view on the two-plane level 3—3—3 etc. of Fig. 2; Fig. 4 is an end view of one of the roller cutters; Fig. 5 is a diagram illustrating one method of laying out the pitch surfaces of these rolling members; Fig. 6 is another diagram illustrating the action of the tooth elements of the said cutters; and Fig. 7 is a longitudinal section of a slightly modified portion of the lubricator construction shown in Fig. 2.

On the second sheet of drawings, Fig. 8 is a composite elevation of the second general exemplification of my improvements—the lower portion of this figure being in partial section on the plane 8—8 of Figs. 9 and 10, and the upper part thereof being in full section on the plane 11—11 of Figs. 9 and 10; Fig. 9 is a sectional plan view on the five-plane level 9—9—9 etc. of Fig. 8; Fig. 10 is another section on the two-plane level 10—10 of Fig. 8; Fig. 11 is a full sectional elevation on the plane 11—11 of Figs. 9 and 10, but showing certain of the parts in a slightly different position from that depicted in the preceding figures; Fig. 12 is a detail sectional view, greatly enlarged, on the plane 12—12 of Fig. 11; Fig. 13 is a diagram similar to that of Fig. 5; and Fig. 14 is an enlarged cross-section showing a special form of cutter tooth for the roller bit member.

The boring tool shown in Figs. 1 to 5 comprises only three principal parts; viz, the hollow head 1, which is attached to the driving stem 4 by means of the reducing coupling 5, and which is rotatable on the longitudinal axis C—C; and the two complementary cutting rollers, 6—6, that are mounted in a U-shaped pocket at the lower end of the rotatable head and are adapted to revolve on the two mutually inclined and laterally offset transverse axes *c—c*, *c—c*. Each of the revolvable cutter members 6 is supported on a large coned journal 7, which is integrally secured, in and to, the said head by means of the socket joint 14 and the three holding bolts

15, 15, 15. The cutter is held in position on its journal by means of the two part bushing 16—16^a, which is provided with a flange 17 that engages with a corresponding groove in the journal member, and which is detachably secured in the hub of the cutter member by the screws 18—18 (see Figs. 2 and 4). Either, or both, of these journal-cutter units may be removed from the head by taking out the cap bolts 15—15—15, and then lifting the member 7 out of its socket support 14; and the revoluble member 6 may then be detached from its cone bearing support by removing the screws 18—18 and thus permitting the split bushing 16—16^a to be withdrawn from its fixed engagement with the cutter and its rotatable engagement with the grooved journal. When the parts are assembled in position on the head, the removal of the screws 18 is rendered impossible by the contact of the flanged end of the bushing with the adjacent face of the head; and the accidental loosening or loss of the bolts 15 can be prevented by filling the recesses, in which their heads are located, with lead or Babbitt metal, or other easily fusible metal.

In the drilling of hard formations it is desirable to avoid any large amount of dragging or scraping action between the toothed surfaces of the revolving cutters and the material at the bottom of the bore hole. In other roller bit constructions, now in use, this is accomplished by making the cutters in the form of cones and mounting these cones in such position on the head that their vertices—i. e., the apices of the conical surfaces—lie in the longitudinal axis C—C of rotation. This arrangement prohibits any offsetting of the axes of revolution of the rolling members, and also necessitates the use of cutters which have a very small diameter at the inner end (i. e., near the vertex of the cone), and which are therefore more subject to accidental breakage or injury at those points. In my improved construction I avoid this last mentioned difficulty, and also retain the advantages of offsetting the cutting members—i. e., the advantages of greater cutting clearances, more rigid supports etc. etc.—by the use of skew-roller bits, whose surfaces have the form of hyperbolic conoids, or hyperbolas of revolution, or “hypoids” as they are sometimes more briefly designated. The manner in which these hyper-conoidic rolling surfaces are generated is known to engineers and does not therefore require detailed description. In most instances the desired form of surface can be obtained with the necessary degree of accuracy by the very simple diagrammatic method indicated in Fig. 5; in which C is the axis, or center of rotation, of the drill head, C—F is the amount by which the axis of revolution of the cutter is offset from this center, and, c —F—C, is the angle at which these two axes are inclined

to each other. Divide the distance C—F into two parts C—A and F—A whose ratio to each other is equal to the velocity ratio, V, between the rolling cutter and the surface over which it moves; and draw the line of contact engagement, A— a , perpendicular to C—F. Through the outer end of the cutter axis, c , draw the perpendicular c — x , and, by trial, find a point, a' , which is so positioned on this line that when it is projected on the line of contact A— a , the distance c — a' , and C— a , bear the same ratio to each other as the distances F—A (or F— h):C—A. In the particular construction here shown this ratio is approximately .58, while in the construction to be described later (see diagram of Fig. 13) it is approximately .45. In order to determine the radii of the rolling surface at intermediate points in the length of the latter I divide the line of contact, A— a , and the axial length, F— c , of the cutter, into an equal number of parts; and from each of the points of division c' , c' , on the outer axis, I draw perpendiculars c' — b' , c' — d' , etc., whose lengths bear the previously chosen fixed ratio (in this case .58) to the corresponding radii, C— b , C— d , etc. of contact engagement. The curve drawn through the points a' , b' , d' , e' , f' , h , is the generatrix of the pitch surface of revolution of the rolling cutter members; and this surface will correspond very closely to the theoretical conoid or “hypoid” that is obtained by the more complex and refined methods of gear tooth generation.

Each transverse disc element of the laterally offset conoidic roller will move circumferentially at a fixed velocity ratio, V, with respect to the circle of its contact with the bottom of the bore hole—(since the ratio between the radii, C— a : c — a' ; C— b : c' — b' ; C— d : c' — d' ; C— e : c' — e' ; C— f : c' — f' etc. is a constant one)—and the engagement between the longitudinally curved cutter surface and the material on which it moves will be a true skew-rolling contact. But this skew or conoidic rolling action also involves, as is well known, a longitudinal or axial slip of the engaged surfaces that produces an endwise thrust on the circumferentially revolving elements of the rotating cutter members. The direction of this thrust and its effect on the cutting action is determined, and to some extent controlled, by the direction and the amount of offsetting of the cutter axis, and also by the form and angular positioning of the tooth elements on the rolling surfaces. In the construction shown on the first sheet of drawings the conoidic rollers are offset rearwardly or backwardly with respect to the direction of rotation of the head—which is indicated by the arrows of Figs. 3 and 6—and the endwise thrust on the rolling elements is then directed inwardly, and tends to relieve the outward pressure of the cutting members 6 on the base of their journal supports 7. If

the rolling conoid members are offset forwardly—as shown in Fig. 8 et seq.—the endwise thrust due to the skew rolling contact is directed outwardly. In most instances I prefer to employ the rearwardly offset cutters, but there are some conditions of operation under which it may be advantageous to utilize the second or reverse arrangement.

The action of the cutting teeth of my improved conoidic roller bit elements is best illustrated by the diagram of Fig. 6. In the case of an apically centered rolling cone bit the plane of revolution of any tooth element, such as the one indicated at T (Fig. 6), is tangent to the circle of rolling contact between that element and the bottom of the bore hole; and the vertex or point of the tooth therefore enters and leaves the material at points, i and i' , which are at substantially the same radial distance from the axis of rotation C. But when the cutter axis is offset, the circumferential lines of movement of the tooth elements, T, (e. g., the line $d''-d-d'-d''$ which makes pitch contact with the bottom of the hole at the point d of Figs. 5 and 6), are inclined to the corresponding circles of rolling contact (e. g., the circle $d-d-d$ of radius $C-d$); and the successive elements of the projecting teeth enter and leave the material at points (such as z and z') that are at different distances from the axis of rotation of the drill. In consequence of this, each tooth point has a composite motion with respect to the surface on which it is acting; viz, a direct downward penetrative movement that is produced by the circumferential rolling of the pitch surface of the cutter on the bottom of the bore hole, and a side wedging or lateral boring action, that is due to the skew engagement, and the relative axial slip, of the conoidic cutting surface on the material. This last component of movement is of substantial benefit in facilitating the rapid penetration, and the breaking and chipping away, of the rock or other hard formation on which these tools are particularly designed to operate; and the elimination of any component of circumferential slip—by the use of conoidic pitch surfaces—prevents any such transverse scraping or grinding action of the material on the tooth edges as results from the use of either cylindrical cutters or of offset cone cutters. My improved “hypoid” roller bits are therefore clearly differentiated—in form and function—both from the apically centered cone roller bits (which have only a circumferential digging action), and also from the offset cone cutter bits and the cylindrical cutter bits, which have a combined chipping and circumferential scraping action on the material.

The relative magnitude of the rolling and side wedging actions of the conoidic cutter teeth may be varied to some extent by changing the form and arrangement of these ele-

ments. If the teeth are arranged as shown in Figs. 1, 2 and 3—i. e., in lines that lie in the plane of the cutter axis (e. g., the plane $F-c'-d'$ of Fig. 5 or 6)—and are interrupted at various points in their length by peripheral or circumferential grooves (such as are indicated at 20—20 etc.) the cross cutting or lateral wedging action of the cutter projections will be considerably greater than it will be when the teeth are “skewed”, or arranged at an angle to the axis of the cutter as in the ordinary skew bevel gear. The latter arrangement is one in which the lines of tooth engagement A— a coincide with the straight line generatrix of the surface of revolution of the hypoid or conoid surface of the cutter, and is one in which these lines of tooth contact with the bottom of the hole are nearly parallel with the radii of the outer rolling circles C— a , C— b , C— d etc.;—as shown, by the fragment of the tooth, Z S, in Fig. 6. Under such circumstances the relative slip between the material and the sides of the teeth is almost exactly parallel to the latter; and this is the arrangement which I therefore prefer to employ when the cross cutting or side wedging action of these teeth is to be reduced to a minimum.

Another feature of improvement which characterizes my improved roller bit construction, is the form and functional action of the end portions of the cutting rollers 6. The outer ends of these rollers are elliptically rounded and recessed to form ribs 21 that are provided with sharp cutting edges 22 on their rearward following sides; and the curved peripheral surfaces of the said ribs are shaped to correspond to the curvature of the side wall of the cavity which is formed by the rotating drill. The ends of the teeth on the conoidic rolling faces form a series of transverse cutting edges that are prolonged and carried around the curved periphery of the rib 21 in the form of cross grooves, 23, of gradually diminishing depth. These rounded, recessed and toothed end-surfaces present an extended cutting and bearing engagement with the boundary zone between the end and the side wall of the bore hole; and not only serve to effectively supplement the action of the conoidic cutting surfaces in the rapid penetration and removal of the material and in the maintenance of the full diameter or “gauge” of the hole; but also act to center the drill and restrain the “whipping” or wobbling of the rapidly rotating mass of the head. The use of these elliptically curved end zones, or rings, on the roller bits also eliminates any sharp angular edge at the outer extremity of the revolving cutters, such as is presented, for example, by the ordinary cylindrical or frusto-conical cutters of the prior art; and this feature of improvement substantially reduces the tendency of the hardened metal teeth to crack off or wear away at these points, and

thus substantially prolongs the effective cutting life of the bit elements.

An important part of my device is a very simple and efficient means for keeping the journal bearing surfaces of the revolving cutters thoroughly lubricated under all conditions of operation. These rotary boring drills are used at all depths; and the ends of the bearing openings (between the bushings 16 and the parts on which they revolve) may be exposed to flushing-water pressures that vary from less than fifty to upwards of two thousand pounds per sq. inch; or the drill may, at times, be operated either in a "dry" hole, or without any circulation of flushing liquid. My preferred form of improved lubricator device is designed to act continuously and uniformly at all depths of immersion; its action is not affected by the circulation, or the rate of flow, of the flushing liquid—i. e., by any differences in pressure inside and outside the drill stem—and it will operate in the same way when the hole is filled with water or when it is "dry."

In the construction shown in Figs. 2 and 3 the lubricator reservoir is forming by coring and boring out the upper portion of the head 1, and closing the upper end of this cavity by a plate 24, which is secured to the top of a small central tube 25, that leads from the end of the drill stem 4 to water discharge passages 35—35 in the lower part of the head. A pair of ducts, 26, lead from the lower end of this annular chamber to recesses at the base of the journal supports 7; and the latter are furnished with passage-ways, such as 27, which lead to the cone-bearing surfaces of the bushings 16—16^a. The lubricator reservoir is provided with a packed annular piston 28 which has an easy sliding fit in the outer cylinder, and which is loosely engaged with the inner tube 25;—the joint between the central tube and the ring and piston members being made water-tight by the compressed packing washer 31. The reducing coupling 5 is pierced with a series of radial holes 32 which open into an annular passage-way around the outer edge of the cover plate 24; and the latter is provided with two or more ducts 33, that lead from this passage way to the upper end of the lubricator chamber. The lower end of this chamber is also provided with a threaded aperture that is normally closed by a screw plug 34.

The annular reservoir is filled with lubricant by inverting the head, removing the plug 34, and pouring or pumping the oil into the space beneath the piston 28. When the head is attached to the drill stem and lowered into the bore hole the water or other fluid outside of the head passes into the space above the piston, through the openings 32—33, and substantially balances the pressure exerted by this same fluid on the oil filled bearing openings around the ends of the jour-

nal shafts 7—7; and the lubricant is forced through the ducts 26—27 to the bearings of the revolving cutters at a substantially uniform rate, by a predetermined force which is applied to the piston member 28, and which is unaffected either by the pressure of the flushing liquid inside the drill stem, or by the rate of flow of that liquid from the drill stem, through the pipe 25 and passages 35—35, to the large clearance space surrounding the rotating and revolving parts. These results are attained by reason of the fact that the difference in static head between the points 7 and 32 is negligible, and the clearance space between the head of the drill and the side of the bore hole is so large that no sensible kinetic difference in pressure is produced by the relatively slow upward flow of the water through this space between these two points. The necessary supply of oil to the heavily loaded bearing surfaces is not therefore interrupted, or interfered with, by the accidental stoppage of the circulation of the flushing liquid; and any danger of the overheating and seizing of these surfaces, when operating at great depths, is therefore eliminated.

In the form of construction specifically illustrated in Fig. 2, the force which is employed to discharge the lubricant from its containing chamber is obtained by the use of a heavy ring of lead or Babbitt metal 29 that is mounted on the central boss of the piston member, and is loosely secured thereto by the screws 30. This construction is, however, only useful for surface operations or for drilling very shallow bore holes, and I, therefore, prefer to employ a relatively powerful spring 36—such as is shown in Fig. 7—for exerting the necessary pressure on the upper surface of the lubricant feeding piston 28. The employment of a spring actuated piston is particularly advantageous when the drill is to be utilized in boring horizontal or inclined holes; or in cases where an exceedingly stiff and viscous lubricant—which requires a relatively great pressure to force it to the bearings—is used. In order to obtain a uniform feed, the tension of the actuating spring must be maintained substantially constant; and in the construction shown in Fig. 7 this result is accomplished—with sufficient exactness for the purpose—by the use of an open wound powerful compression spring 36, whose initial, unflexed, length is several times the maximum stroke of the piston 28; and which is compressed until its operative length approximates one-third or one-fourth of its original length;—its minimum length being about four times the longitudinal feed movement of the piston member. The variation in the expansive force of the spring—at the two ends of the piston stroke—is then only from 8% to 12%; and this can, if necessary, be still further reduced, either by increasing the degree of maximum compression of the

spring coils, or by increasing the ratio between the minimum length of the compressed element and the minimum length of piston movement. The compressed spring, 5 36, is conveniently enclosed, and protected by, a light guard tube 37, which is coupled at its lower end to the tube 25, and which is clamped at its upper extremity to an inwardly projecting flange on the drill stem coupling 38. In this case the space above the piston, and the communicating annular slot in which the spring 37 is located, are in direct communication with the water or other fluid which surrounds the outside of the drill stem through the large openings 39; and the fluid pressures on the two ends of the column of lubricant are thus substantially equalized under all conditions;—the rate of feed being determined and controlled solely by the predetermined tension of the spring 36.

The use of a central water passage through the body of the head—e. g., the tube 25—and the utilization of the large annular space surrounding that passage as a lubricant chamber, has a great advantage in reducing the necessary length of the oil reservoir, as compared with that required when a central lubricant containing tube is employed. For example: A standard nine and seven-eighths drill head of my improved construction, may be provided with an oil reservoir of nearly nine inches internal diameter; whereas the diameter of a center tube lubricant holder, which must extend up into the drill stem, is limited by the size of the said stem to about two inches. The cross sectional area of this annular reservoir is nearly twenty times that of the center tube holder; and a reservoir of this form, nine inches in depth, will hold as large a volume of lubricant as a tube holder of nearly fifteen feet in length. The general type of hollow head construction shown in Figs. 1 to 4 is therefore a very short and compact one—(in the case of a nine and seven-eighths drill the overall length of the head need not exceed fifteen inches)—and in the spring actuated form of lubricator device shown in Fig. 7 the spring and the spring tube members, 36 and 37, are also relatively short (e. g., a little more than twice the length of the head). This longitudinal compactness of structure is particularly important in connection with the last described form of lubricator; and it would, in fact, be impracticable to use any such form of constant tension spring feed device in connection with a long stroke central tube container, because of the impossible length of coil spring required in such a case. Those skilled in the art will also readily understand that it is impossible—for this same reason—to use a weight such as is shown in Fig. 2 in place of a spring, when any large amount of pressure is to be exerted on the piston 28. It would require a cylinder of lead of the full

diameter of the piston 28 and several feet in length to obtain the same effect as is secured by the initially compressed, and therefore relatively short, coil 36; and such a very bulky and heavy construction would be objectionable and impractical. If it is desired to use a gravity pressure alone to effect the feed of the lubricant, such pressure should be obtained by utilizing a whole or a part of the weight of the drill stem itself— in the manner disclosed in my copending applications Ser. No. 273,715 (Pat. 1,388,496), Ser. No. 333,506 (Pat. 1,399,831), or Ser. No. 582,046, filed Aug. 15, 1922—and thus avoid the addition of other extraneous and unnecessary weights for this purpose.

Figs. 8 to 13 inclusive illustrate an application of my improvements to the type or species of rotary boring tool that is generally designated as the cross roller bit drill. In this organization the revolving cutter members comprise; two inclined "side rollers", 6^a—6^a, mounted on journals, 7^a—7^a, that are here shown as each offset forwardly in the direction of rotation (see Figs. 9 and 10); and two pairs of "cross rollers", 40—40, which are rotatably supported on the horizontally disposed shafts 41—41, that are also laterally offset with respect to the axis of the head 1^a. Each of the four cutter elements 6^a, 6^a, 40, 40, is housed and shrouded in its own separate recess in the bottom of the head; and the journal shafts, 7^a and 41, are rigidly supported at each end by the adjacent walls of the housing pockets, and are detachably secured in position therein by screwing their inner shouldered ends into threaded sockets (such as are indicated at 42—43, in the cross-sectional views of Figs. 9 and 11), or in any other suitable manner. In order to prevent the accidental loosening of these shafts, when the drill is in operation, the outer squared-socket ends may be covered by Babbitt metal, or other fusible metal, seals, that can be readily melted away by a hand torch, when it is necessary to remove the said shafts for the replacement of the cutter elements.

The two inclined side cutters 6^a are each provided with pitch surfaces, of hypoidic or hyper-conoidic form, which are laid off in the same manner as those shown in Figs. 2, 3 and 5; but in this second exemplification of my invention the line of contact, A—*a*, *a*'—A', between the conoidic surface and the bottom of the bore hole is inclined upwardly instead of being substantially horizontal (see diagram of Fig. 13). The cutting teeth of these side roller cutters 7^a are skew elements which are substantially parallel to the right line generatrices, or lines of rolling contact, of the hypoidic surfaces on which they are formed—like the elements indicated by the dotted lines, Z—S of Fig. 6—and they may, therefore, be cut in an ordinary milling machine by placing the mandril blank at the

proper horizontal and vertical angle to the line of feed. These forwardly offset conoidic cutters will have a true, skew-rolling engagement with the reversely curved (convex) bottom of the bore hole; and the skew teeth thereon will have a combined circumferential digging and side wedging or chipping effect on the material into which they penetrate, without being subjected to any cross drag or transverse grinding action that would tend to wear away their cutting edges. The outer ends of the rollers terminate in elliptically rounded edge-ribs or rings 21^a, that are shaped to conform to the curvature of the terminal zone between the bottom and sides of the hole; and these ribs are provided with tapered cross grooves 23^a that form continuations of the longitudinal skew teeth on the conoidic rolling surfaces;—the structural character and operative functions of these terminal rib elements being the same as those of the correspondingly numbered and previously described parts of the two roller bit construction of Figs. 1 to 6.

Each of the inner cross roller cutters, 40, is preferably made in two independently rotatable parts that have plain frusto-conical surfaces of slightly different angle, so that the general surface of the unit approximates that of a hyper-conoid; but in order to obtain the proper diameter of shaft support at the inner ends of the cross cutters, these ends are of larger size than is required to secure a true skew-rolling contact with the central portion of the bore hole bottom. In consequence of this the different portions of the toothed surfaces must have some relative circumferential slip or drag, on the material over which they move, and this tends to grind off the edges of the cross roller bit teeth. But this action is diminished by the possible independent revolution of the inner and outer members of the cross bit units, 40, 40; and the remaining wear, or abrasion, on those teeth is of relatively small importance, as compared with the preservation of the cutter elements on the faces and ends of the main side rollers 6^a, because the latter cutters remove nearly 90% of the material from the bottom of the bore hole.

The head 1^a may also be provided, in some cases, with a third set of "reaming" rollers, 45, 45, etc., which are uniformly disposed in pockets on the peripheral surface of the head, and are rotatably mounted on vertical journals 46—46 that are similar in construction to those which carry the main side rollers 6^a. In order to permit of the ready removal of these vertical journal shafts, the upper portion 1^b of the head is made separate from the lower portion 1^a, and is united thereto by a flanged screw joint that covers the ends of the said shafts when the parts are assembled.

The upper tubular section 1^b constitutes

the lubricator reservoir and is bored to receive a sliding piston member 28^a, which is shown at its upper limit of movement in Fig. 8 and at its lower limit of movement in Fig. 11. The central portion of this reservoir is traversed by a water tube 25^a, which is secured to the lower member 1^a of the head, by the flange collar 47, and to the upper member 1^b, by the washer and nut coupling 48. This tube serves to conduct the flushing liquid from the interior of the drill stem 4^a to the cored passage ways 35^a—35^a that open into the pockets in which the roller cutters, 6^a, 6^a, 40—40, are housed. The exterior of the tube is finished to form a close sliding fit with the central hub of the annular piston 28^a; and it is provided, at an intermediate point in its length with two symmetrically disposed brackets, 50—50, each of which carries a deeply grooved sheave or pulley element 51, similar in form to the one shown in enlarged detail in Fig. 12. The upper end of the body 1^a is cored out to form a rectangular recess 52; and is also longitudinally perforated by two inclined holes 53—53 that are closed at the bottom by the recessed heads 54—54. The threaded ring or flange portion of this body is further provided with two diametrically opposite bosses 55, 55, which are perforated to receive the pintle pin supports of two levers 56, 56; and the outer extremities of these levers are threaded to receive stud bolts 57 (as best shown in Fig. 12) on which the grooved pulleys 58—58 are rotatably mounted. The intermediate portions of the lever members, 56, are flexibly connected to the upper extremities of two powerful tension springs, 36^a, 36^a, which are positioned in the cylindrical recesses, 53, 53, and are secured at their lower ends to the heads 54, 54.

The two spring actuated units, 56—57—58, are operatively coupled with the movable piston 28^a by the flexible cords 60—60; which are attached at their lower ends (as at 61) to the levers 56, 56, then pass up over the fixed pulleys 51, 51, then down around the lever supported sheaves 58, 58, and thence to the eye connections on the lower side of the piston body;—thus forming a three-fall block and tackle connection between the spring-lever-members and the piston member. With this arrangement the change in the length of the springs 36^a is only about one-ninth of the linear movement of the piston; and the resultant change in the driving tension of the expanded coils is negligible. In most cases this feeding pressure on the lubricant may be kept sufficiently uniform by omitting the fixed pulleys, 51—51, and attaching the lower ends of the cords 60—60 to the brackets 50—50—thus producing a two-fall block and tackle connection—but in this case the vertical movement of the lever arms is increased; and the stroke of the piston

correspondingly diminished. I therefore prefer the three-fall construction previously described.

The lower end of the annular lubricant chamber is in communication with the bearings of the cross roller cutters through the recesses, 52—53, and the passages, 62—62 and 63—63, that lead therefrom to the stepped surfaces of the journal shafts 41—41. The bearings of the reaming cutters 45 are supplied with oil through the conduits 26^a and 64; and the journal bearings for the main side cutting rollers, 6^a 6^a, are in communication with the conduits 64, 64, of the two superimposed reaming cutter shafts, through the passage ways 65 and 27^a. The space above the piston 28^a is in open communication with the fluid surrounding the drill head through the holes 39^a 39^a; and the pressure of this fluid on the ends of the oil filled bearing openings around the various shafts 7^a, 41, 46 etc., is therefore substantially balanced by its equal pressure on the upper end of the piston covered oil column. Under such conditions the lubricant is uniformly and continuously supplied to all of the revolving cutter bearings by the substantially uniform pressure of the spring actuated piston; and this action is independent of, and is not affected by, the pressure of the flushing liquid inside the drill stem, or by the differences of pressure due to a varying flow of such liquid through the passages 25^a—35^a etc.

When the piston has reached the lowermost limit of its stroke—as illustrated in Fig. 11—there still remains a considerable amount of lubricant in the recesses of the lower head member 1^b, that may serve as a gravity-fed reserve, in case the drill is operated for unusually long periods, without renewal of the cutter bits or of the oil. When the drill is “pulled” from the bore hole any one of the revolvable rollers may be easily removed by unsealing and withdrawing its shaft support; and the lubricant chamber may be refilled by laying the head on its side, removing the screw plug 34^a, and drawing back the piston 28^a by means of suitable hooks inserted through the equalizing openings 39^a. When the screw plug 34^a is reinserted—after thus filling the chamber—it can be sealed in place by a fusible plug of metal, or more conveniently by driving a block, 66, of cork or wood, into the rough threaded end of the orifice.

The cross roller bit construction last described is necessarily somewhat more complicated (particularly when auxiliary reaming rollers are used) than the two-roller bit construction of Figs. 1 to 7; but this second embodiment of my invention comprises only a relatively small number of exposed parts, and all of these are of strong and rugged character. The lubricator feed mechanism, which is the only part of the structure that contains any relatively light members, is com-

pletely enclosed and surrounded by the rigid and massive walls of the drill head; and all parts of this mechanism are immersed in the mass of lubricant, and are thus thoroughly protected against either wear or corrosion. And in case of necessity this mechanism can be easily reached by removing the plate and nut coupling 48 and then unscrewing the upper tubular part 1^b of the head from the lower body portion 1^a. This separation of the two head members also permits of the withdrawal of the shafts 46, etc., and the renewal or removal of the reaming bits, 45, etc. The tool may, if desired, be used without the last mentioned cutters; in which case the lateral openings from the central oil passages 64 must be temporarily closed by suitable plugs.

The form of the individual cutting elements on the conoidic surfaces of the rolling bits may be varied according to the character of the formation to be drilled. In Figs. 1, 2, 3 and 4, I have shown teeth of isosceles form which are disposed in axial planes; in Fig. 6 I show teeth (T) of similar form that may be arranged either in axial planes, or in the planes (Z S) of skew contact between the rolling surface and the floor of the bore hole; in Figs. 8, 9 and 10, I have likewise shown skew teeth of isosceles cross section; and in Fig. 14 I illustrate, on an enlarged scale, another form of cutting rib that possesses certain specific advantages when used in connection with other features of my present improvements. This last depicted form of tooth, T^a, has a sharp edge on its advancing side, i. e., the edge that first bites into the material as the revolvable bit is rotated with the drill head; and the clearance grooves between these successive edges are of approximate semi-parabolic form in cross section. Those portions of the teeth which lie outside of the pitch circle, $d'-d'$, of the conoidic rolling surface, travel in a curtate-cycloidal path, and therefore exercise a slight shearing action on the material below the plane $d-d$ of rolling engagement; and the axial slip, or twist of the teeth—due to the skew rolling action—also produces a lateral wedging or chipping effect that exerts a reciprocal thrust on the tooth edges. The unsymmetrical saw-toothed form of rib shown in Fig. 14 is particularly well adapted to withstand these composite pressures; and it possesses the further property of being self sharpening; i. e., any circumferential slip of the roller on the material—due to a temporary resistance to its axial revolution etc.—will grind or abrade the back face of the tooth, and thereby renew the forward cutting edge instead of dulling or rounding it. The shallow rounded form of the semi-parabolic clearance grooves between the teeth is also of substantial advantage, because such grooves cut away only a small amount of the

roller body (and this is of particular importance in the case of the roller elements that are positioned near the axis of the drill head); and also because they present no sharp angles, and form no thin edge portions, that can interfere with the uniform hardening and tempering of the metal during the course of manufacture, or that can result in undue local heating and softening, or tempering, of the tooth edges when the bit is in use.

Those skilled in this art will now observe that, in addition to the general features enumerated in the introductory paragraphs of this disclosure, my invention comprises certain definite characteristics of mechanical organization of which the more important are the following: First, the provision of laterally offset or staggered cutter elements, the pitch surfaces of which have a true skew-rolling contact with the bottom of the bore hole, and the teeth of which have a combined circumferential digging and lateral chipping or cross-cutting action on the material therein; second, the provision of special forms of cutting tooth elements which effectively resist the pressures and stresses to which they are subjected by these combined digging and cross cutting actions, which will be "self sharpening" and which will not be injuriously affected by large changes of temperature, either during manufacture or when in use; third, the provision of cutting rollers which have elliptically rounded end surfaces that conform in curvature to the side wall of the bore cavity and have an extended shearing and bearing contact therewith—thereby eliminating any sharp or acute end-edges or any sudden change in angle in the working length of the cutting faces, and thus avoiding the danger of breakage or rapid change in shape at those parts of the toothed surfaces that are relied upon to maintain the full diameter or gauge of the hole; and fourth, the arrangement and mounting of the rolling cutters in such manner as to permit of their ready removal and replacement or renewal without dismantling or disassembling other portions of the drill head. With the preceding disclosure as a guide, those familiar with the use of rotary boring tools will be able to design various other forms of such tools that will embody—in whole or in part, as may be desired—the hereinbefore described invention. Any one of my improved lubricator devices may, for example, be effectively utilized in conjunction with the other elements of a horizontal disc drill (such as is disclosed in my prior Patent No. 1,338,601), or of a vertical disc drill (such as are described in my copending applications, Ser. Nos. 273,715; 300,004; 380,033 or 380,034 etc.) as well as with such types of roller bit tools as are herein illustrated. The particular forms of bor-

ing mechanism which I have chosen to exemplify my present improvements are not therefore to be regarded as limiting the range of application thereof; or as serving to restrict the scope of what I have invented and herein claim: to wit—

1. A rotary boring tool comprising the combination of a drill head, with a cutting roller provided with a concave conoidic surface and revolvably mounted on the said head in an offset relation to the longitudinal axis thereof.

2. In a rotary boring tool the combination of a head, and a plurality of axially offset cutting rollers mounted thereon, each of the said rollers having a conoidic surface adapted to make a true skew-rolling contact without dragging and scraping on the surface on which the tool is operating.

3. In a rolling bit drill the combination of a head, a journal shaft detachably locked thereto, and a conoidic cutter member revolvably supported on the said shaft and provided with a concave conoidic surface that is adapted to make skew-rolling engagement without dragging and scraping on the material on which the drill is operating.

4. In a rotary boring tool the combination of a head, and a pair of laterally offset cutting bits revolvably mounted thereon and provided with longitudinally toothed conoidic surfaces adapted to make skew-rolling engagement without dragging and scraping on the material on which the bits operate.

5. In a rotary boring tool the combination of a head, a pair of laterally offset and inwardly inclined journal shafts detachably locked thereto, and a pair of concaved conoidic cutting members revolvably mounted on the said shafts and provided with longitudinally toothed surfaces that are adapted to make rolling contact with the bottom of the bore hole.

6. In a rotary boring drill the combination of a rotatable head, and a concave rolling member mounted thereon and offset with relation to the axis of rotation thereof, the said member being provided with longitudinally disposed cutting elements of an unsymmetrical saw tooth form substantially as described and for the purpose specified.

7. A roller bit drill which comprises a rotatable head, and a pair of offset cutter members revolvably mounted thereon, each of said members being provided with a conoidic pitch surface and with longitudinally disposed ribs of an unsymmetrical saw-tooth form that are adapted to make skew-rolling engagement without dragging and scraping on the material at the bottom of the drill hole.

8. In a rotary boring tool, the combination of a head, with a concaved cutter member revolvably mounted thereon and offset with relation to the axis of rotation thereof, and

provided at its outer end with an elliptically rounded portion that is adapted to make extended contact with the terminal zone between the side and bottom walls of the bore hole. 5 hole.

9. A rolling bit drill which comprises the combination of a rotatable head, and a pair of offset cutting members provided with concave conoidic surfaces revolvably mounted thereon, each of the said members being pro- 10

vided with longitudinally disposed teeth adapted to make skew-rolling engagement with the bottom of the bore hole and with rounded end portions adapted to make an extended cutting and bearing engagement with the side wall of the said hole.

In testimony whereof I have hereunto set my hand.

FRANK L. O. WADSWORTH.

CERTIFICATE OF CORRECTION.

Patent No. 1,708,288.

Granted April 9, 1929, to

FRANK L. O. WADSWORTH.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, line 88, for the word "outer" read "cutter"; page 5, line 3, for the word "minimum" read "maximum"; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 7th day of May, A. D. 1929.

(Seal)

M. J. Moore,
Acting Commissioner of Patents.

CERTIFICATE OF CORRECTION.

Patent No. 1,708,288.

Granted April 9, 1929, to

FRANK L. O. WADSWORTH.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, line 88, for the word "outer" read "cutter"; page 5, line 3, for the word "minimum" read "maximum"; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 7th day of May, A. D. 1929.

(Seal)

M. J. Moore,
Acting Commissioner of Patents.