

July 12, 1927.

F. L. O. WADSWORTH

1,635,592

ROTARY DRILLING TOOL

Filed March 10, 1921

2 Sheets-Sheet 1

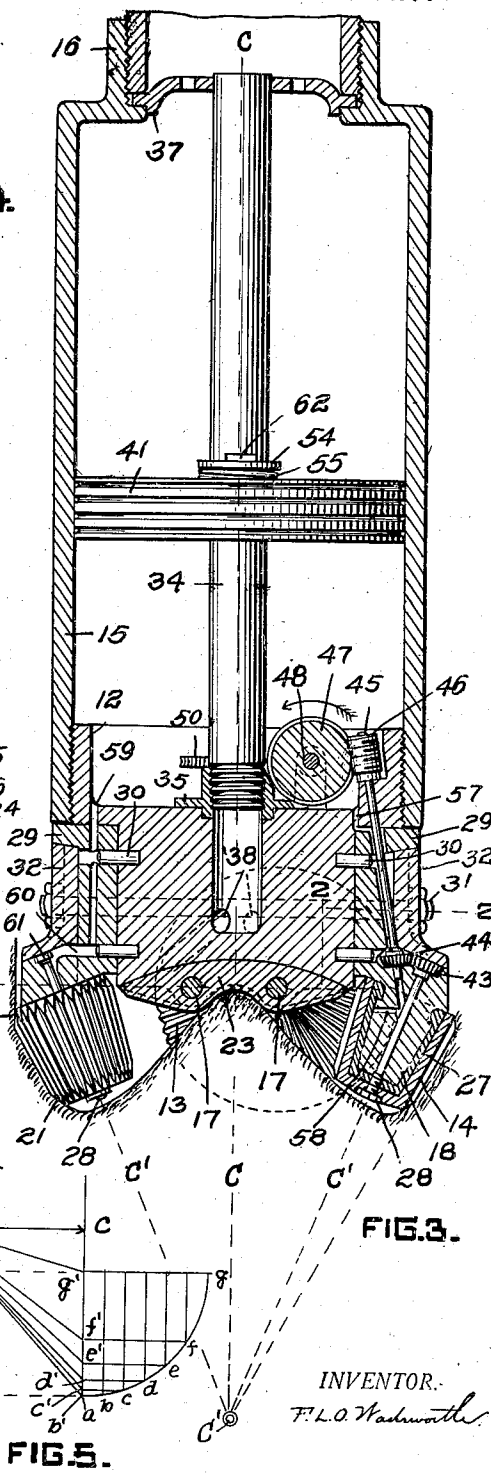
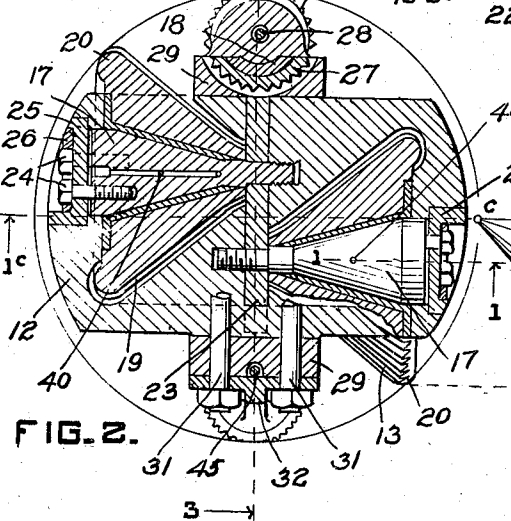
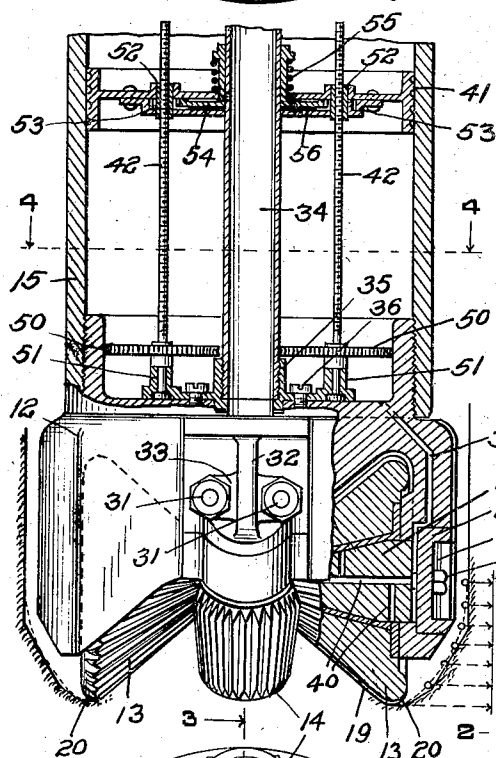
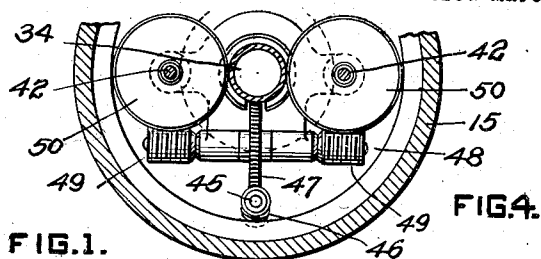


FIG. 5.

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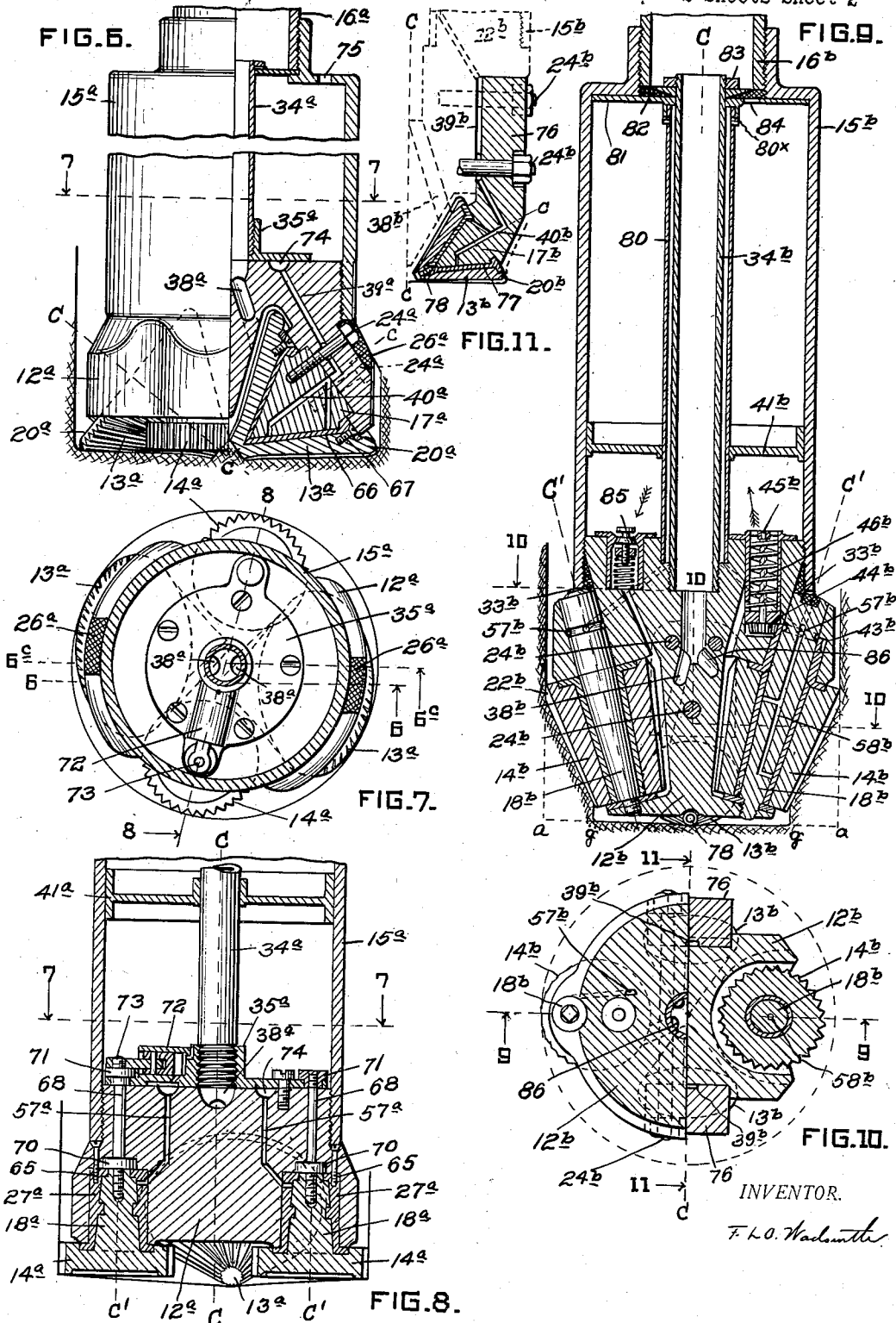
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2 Sheets-Sheet 2



Patented July 12, 1927.

1,635,592

UNITED STATES PATENT OFFICE.

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

ROTARY DRILLING TOOL.

Application filed March 10, 1921. Serial No. 451,223.

My invention relates particularly to that type of rotary boring tools which utilize a plurality of revolvable cutters to perform the drilling operations; and one of the main objects of this invention is to provide a system of cutter members that have an overlapping and mutually complementary action in that part of the drill hole from which the largest amount of material must be removed, viz, the outer circumferential zone at the bottom or end of the cylindrical cavity in which the drill is operating. This improved arrangement of complementary cutter elements—and the superimposed and combined action thereof on the material near the side wall of the hole—increases the speed of the drilling operation; decreases the strain and wear on those portions of the cutter surfaces that are ordinarily subjected to the most severe duty, and thereby prolongs the effective life of the revolving bit members; and also ensures the continued maintenance of the desired "gauge" or diameter of the bore hole as the drilling proceeds.

Another object of my invention is to provide a system of mutually complementary cutter members each one of which makes rolling engagement with the material on which it operates; thereby eliminating the cross drag or circumferential slip of the cutter teeth on the end or side wall of the bore hole, and avoiding the abrasion or injury that may result from such shearing movement.

A further object of the present improvements is the provision of a means for continuously lubricating the bearings of the cutter members, which is actuated and controlled by the movement of those members, and is in no way affected by the pressure, or the rate of flow, of the liquid that is used in flushing out and carrying away the excavated material. One of the advantages of this feature of improvement is that the rate of feed of the lubricant may be preadjusted to the rate of movement of the revolving cutters, and this predetermined ratio may be automatically maintained under all conditions of operation.

Still another object of this invention is to provide a system of delivery or discharge passages for the flushing liquid, whereby the latter is directed obliquely or tangentially against portions of the revolving cutter surfaces that are moving in a direction opposite to that of the liquid streams. The

particular purpose of this arrangement, and this feature of operation, is to cause the flushing liquid to impinge on the tooth elements of the cutters at a high relative velocity, and thus secure a very effective scouring and cleaning action that will dislodge and wash away the material that adheres to, or is wedged between, the cutting teeth.

Other objects and advantages of my invention will be developed more fully by the consideration of the three illustrative embodiments thereof, which are shown in the accompanying drawings; in which:

Fig. 1 is a side elevation of one exemplification of my improved drill construction—the lower right hand portion of this view being shown in partial section on the plane 1—1 of Fig. 2, and the upper part thereof being in full section on the plane 1^c—1^c of the same figure. Fig. 2 is a sectional plan view on the two plane level 2—2 of Fig. 3. Fig. 3 is a longitudinal section (with certain parts in elevation) on the plane 3—3 of Fig. 2. Fig. 4 is another sectional plan view on the plane 4—4 of Fig. 1. Fig. 5 is a diagram for determining the path followed by the end edge of one of the rolling cutters shown in Figs. 1, 2 and 3.

On the second sheet of drawings—which illustrate two other embodiments of my invention—Fig. 6 is a partial side elevation of a drill head, the lower part of which is shown in half section on the plane 6—6 of Fig. 7, while the upper portion is correspondingly sectioned on the central plane 6^c—6^c of that figure. Fig. 7 is a sectional plan view on the plane 7—7 of Figs. 6 and 8. Fig. 8 is a longitudinal section, partly in elevation, on the plane 8—8 of Fig. 7. Fig. 9 is a longitudinal central section—as on the plane 9—9 of Fig. 10—of a third illustrative form of my improved boring tool. Fig. 10 is a sectional view on the two plane level 10—10 of Fig. 9. Fig. 11 is a sectional elevation—on the plane 11—11 of Fig. 10—showing one member of this last construction.

In the construction shown in Figs. 1 to 4 inclusive the head of the drill is made up of a lower member 12, which carries the revolving cutter members 13—13 and 14—14; and an upper tubular member, 15, that is threaded at one end to engage with the lower member 12, and at the other to engage with the hollow drill stem 16. The cutters 13—13 are mounted on journal shafts 17—17 which

lie in a plane that is normal to the longitudinal axis, C—C, of the drill head, and which are symmetrically offset with respect thereto; and the complementary cutters 14—14 are revolvably supported on stud shafts, 18—18, which are positioned on opposite sides of the head and are disposed in nearly parallel relation to the said central axis thereof. The symmetrically offset cutting members, 13, are each of hypoid, or hyper-conoidic, form (similar to those more fully described in my copending application Ser. No. 442,333 filed February 3rd, 1921) and are adapted to make a true skew-rolling contact with the end of the bore cavity on which they rest. The pitch rolling surfaces of these hypoid cutters are provided with longitudinally extending teeth 19, which may be disposed in axial planes (as here shown), or which may be arranged at an angle to the axis of revolution (like the teeth of skew bevel gears); and the outer end peripheries of the toothed surfaces terminate in elliptically rounded edges 20, that contact—at diametrically opposite points—with the cylindrical side wall of the bore hole (see Fig. 2). When the drill head rotates on its central axis C—C the successive circumferential elements $a-b-c-d-e-f-g$, on the maximum peripheral zone of this curved edge, will describe circles of radii, C— a , C— b' , C— c' etc.; and when these radii are laid off on successive horizontal planes corresponding to the level of the elements a, b, c, d , etc., a series of points $a'' c'' d'' f''$ and g' are obtained which determine the surface of rotation that is described by the said edge in the operation of the tool. If the rollers, 13—13, were used alone, all of the material within the annular zone, that is bounded by the radii C— g' and C— a ,—which in this case comprises over 45% of the total cross sectional area of the bore hole—would have to be removed by the tooth elements, $a b c$ etc., on the curved edge portions 20. This would impose a very severe duty on these end elements of the revolving cutters, and the wear and loss of shape due to this excessive duty would be greatly aggravated by the fact that the engagement between them and the curved-side-wall zone of the bore hole would not be a rolling engagement but would be a sliding and shearing one. In order to avoid this action, and relieve the edge portions 20, 20 of any abnormal cutting or shearing function—such as would quickly dull them in hard rock drilling—I provide the complementary cutters, 14, 14; which are either frusto conical in shape (when they are so mounted that their vertices intersect in the axis of rotation—as at C' Fig. 3), or are hyper-conoidic in form (when they are so positioned that their axes of revolution are offset with respect to the central line C—C of the head); and which are of such diameter that their rolling surfaces engage with the end-side-wall zone outside of the curved surface $a b'' c''$ etc. These complementary cutters—which may be designated as “vertical spindle” cutters because of their position and character—are provided with longitudinally extending chisel teeth similar in form and arrangement to the corresponding elements 19; and the ends of these teeth are beveled off to form leading and trailing edges 21—22 (see Fig. 3) which cooperate with the curved edges, 20—20, in removing the material from the superimposed, or overlapping, zones of action, adjacent to the points $a-b''$ and g' .

The action of the hyper-conoidic toothed faces of the rollers 13—13 forms a correspondingly curved end surface that constitutes the mate of the rolling hypoids; and this end surface necessarily presents a central stem or “neck” that is not directly engaged—except at its sides—by the rolling cutter elements. As the action continues this central stem or neck gradually elongates, and will ultimately be broken off in sections by the vibration or lateral oscillation of the revolving and rotating members. But in order to ensure its more prompt and continuous removal I may provide the improved construction, herein shown, with a hardened steel plate 23, which is inserted in a cross slot that is milled in the end of the head member 12 and is rigidly clamped therein by the shouldered and threaded ends of the journal shafts 17—17. After these shafts have been screwed in place, their outer slotted, or socketed, ends are covered and rigidly clamped to the head 12 by means of the washer and bolt elements 25—24; and the latter parts may be locked against accidental loosening or displacement by the fusible metal seals 26.

The vertical spindle cutters 14 are held in position on their stud shaft supports by means of shouldered bushings, 27, that are split longitudinally—to permit their engagement with the grooved stems of the stud shafts 18—and are clamped in the coned sockets of the cutters 14 by means of screws 28 (see Fig. 3). Each of the stud shaft supports 18 is preferably formed as an integral part of a block 29; and these blocks are rigidly secured to the head 12 by means of the dowel pins 30, 30 etc. and the cross bolts 31—31. A ribbed washer 32 is preferably interposed between the outer face of each block 29 and the clamp nuts on the ends of the bolts 31, and the latter are locked in place by fusible metal seals 33 (see Fig. 1).

The upper tubular member 15 of the drill head is centrally traversed by the tube 34, which is attached to the lower member 12 by means of the flanged collar 35 and the cap screws 36; and which is engaged at its

upper end by a perforated collar 37 that is interposed between the said tubular member and the drill stem 16. This central tube serves to convey the flushing liquid from the interior of the drill stem to the recess in the upper end of the head 12, and thence—through the passage ways 38, 38—to the rearward sides of the recesses in which the cutter members 13—13 are housed and shrouded. These passage ways are preferably inclined at such an angle (see dotted lines of Fig. 3) as to direct the streams of flushing liquid tangentially against the upwardly moving surfaces of the hyper-conoidic rolling cutters, so as to most effectively dislodge and wash away the chips and dirt that adhere to the teeth of the revolving bits as they leave the material.

The annular space between the tubular members 15 and 34 constitutes a lubricant chamber, which is in communication with the bearing surfaces of the journal shafts 17 through a series of passages 39—40 etc. (best illustrated in Fig. 1); and which is also connected with the bearings of the vertical spindle cutters, 14, 14, by means of the openings shown in the sectional view of Fig. 3. The upper end of the annular lubricant chamber is tightly closed by the piston 41, which is moved longitudinally therein by the screws 42, 42. These screws are positively driven, at a predetermined speed, by the revolution of one or more of the rolling cutters; and the lubricant is thereby forced to the bearings of these members at a rate which is directly proportioned to their angular velocity;—the piston movement, and the resultant rate of feed, being independent of, and unaffected by, either the pressures, or the flow, of the flushing liquid in any part of the system. In the exemplary embodiment shown in Figs. 1 to 4 the driving screws 42—42 are actuated, in synchronism, from a single one of the vertical spindle cutters 14, by means of a train of gearing which comprises; (1) the bevel gear 43 that is secured to the upper end of the clamp screw 28 and which therefore revolves in unison with the interlocked bushing and cutter members 27—14; (2) the associated bevel gear 44 which is attached to the lower end of a shaft 45 that extends upwardly through suitable bearings in the block 29 and the adjacent part of the head 12; (3) the worm 46 that is secured to the upper end of the shaft 45; (4) the worm wheel 47 that is mounted at the center of a short shaft 48 which is carried by the flanged collar 35; (5) the worms 49—49 at the opposite ends of the shaft 48; and (6) the worm wheels 50—50 which are secured to the lower ends of the said screws 42—42. The screws themselves are rotatably held against endwise movement by the bearings 51—51 on the collar 35, and are engaged

with the piston 41 through the medium of nuts 52, 52 that are rotatably mounted in the said piston. The central portions of these nuts are enlarged to form small pinions 53, 53, that are engaged by an annular spur gear 54, which is rotatably mounted on the central tube 34 and is normally held in close pressure engagement with the piston 41 by the spring 55 and the soft packing ring 56.

The lower part of the shaft 45 and the gear elements 43—44, are positioned in suitable recesses in the block 29; and can be readily reached by removing the superimposed cap or washer 32. The oil is conducted from the lubricant chamber to these recesses by a passage way 57; and passes thence to the coned bearing surfaces of the adjacent cutter 14, through the openings around the shafts 45 and 28 and the lateral ducts 58.

Both of the complementary cutters, 14, may be connected to the screws 42—42 by separate trains of gearing, similar to the one shown at the right of Fig. 3;—in which case the form and arrangement of the recesses, oil passages, etc., in the left hand block and stud shaft support 29—18, will correspond to that just described. But in the particular form here shown the bearing of the left hand spindle roller is supplied with lubricant through a vertical passage way 59, that communicates with the central oil ducts in the stub shaft 18, through the dowel pin opening 60. In this case the clamp screw 28 is also preferably extended up through the central passage way of the stub shaft, and is provided at the top with a screw collar, or nut 61, that serves to assist the seal at the lower end in preventing any accidental loosening of the said screw.

The operation of this rotary boring tool organization will be readily understood by those skilled in this art. When the drill head is rotated the four cutter elements 13—13, and 14—14, will be revolved on their journal supports by the contact of their toothed peripheries with the material on which they rest; and the form and arrangement of these rotating and revolving cutters is such that there is, in each case either a straight rolling or a skew rolling engagement between their pitch surfaces and the bottom and side walls of the bore hole. The teeth on the sides of the cutters 13—13 act on the material at the end of the hole and progressively deepen it; and the teeth of the two complementary cutters, 14—14, act on the terminal boundary surface, between the end and the finished side wall of the bore cavity, and serve to remove the greater part of the material from the zone traversed by the curved end peripheries 20—20 of the first set of cutters 13—13; thus relieving the cutting elements on these ends

from the excessive shearing duty that would otherwise be imposed on them, and enabling the said elements to effectively cooperate with the terminal portions 22, (of the second set of cutters) in always maintaining the desired diameter of the hole. The true rolling engagement of the main pitch surfaces of all the cutters with the material on which they respectively act, eliminates any circumferential slip or "cross drag" of the tooth elements on either the bottom or side walls of the cavity; and this enables the drill to operate for long periods on hard rock formations without any undue wear of the teeth, or any sensible loss of efficiency; and the mutually cooperative and overlapping action of the four toothed surfaces, 20—20—22—22, ensures a continued maintenance of the "gauge" even when one or more of the said surfaces have been accidentally destroyed or badly injured by some abnormal occurrence. The rate of feed of the lubricant to the bearing surfaces is directly proportioned to the rate of revolution of the cutters; and this feed will be maintained as long as the cutter movement continues, regardless of the pressure to which the top of the piston 41 is subjected, and regardless of the conditions under which the tool may be operating. The size of the annular lubricant chamber and the proportions of the gear elements which connect the cutters with the movable piston member, are preferably such that the tool can be operated for 24 hours or more without exhausting the supply of oil; and these proportions can be readily varied, to meet particular requirements, by changing the ratio between one, or both, of the worm and worm wheel connections, 46—47 and 49—50.

When the drill is withdrawn from the hole any one of the cutter members, 13, 14 or 23, may be readily removed from the head, and replaced by a new, or a resharpened, bit; and the piston 41 can be easily returned to its uppermost position by removing the guide plate 37, and using a tubular socket wrench to engage and turn the flanged end 62 of the gear 54. The lubricant chamber can then be refilled through a suitable capped opening at one side of the piston, or in any other convenient way; and the tool will be ready for another run.

In the construction shown in Figs. 6, 7 and 8, the head of the tool is also made in two sections;—a lower section 12^a, which carries the four complementary cutter members 13^a—13^a, 14^a—14^a; and an upper tubular section 15^a, which is screwed thereon, and which is threaded at its top to receive the end of the driving drill stem 16^a. The cutters 13^a are revolvably mounted on inwardly inclined stud shafts 17^a, which are symmetrically offset with respect to the longitudinal axis C—C of the drill head;

and the cutters 14^a—14^a are secured to, or are integral with, vertically disposed shafts 18^a, 18^a which are journaled in the split bushings 27^a, 27^a that are detachably secured in the head by the screws 65, 65 etc. The cutters 13^a are held in position on the coned stud shafts 17^a by means of the split flanged bushings 66, that are clamped to the cutters by the screws 67; and the stud shafts themselves are rigidly locked in their supporting sockets on the head by the screws 24^a—24^a, the heads of which are preferably covered with fusible metal seals 26^a, 26^a. Each of the vertical cutter shafts 18^a is also provided with an extension shaft 68, which has an enlarged head 70 that engages the top of the split bushings 27^a, and which carries, at its upper end, a screw collar 71 that cooperates with the parts 27^a and 70 in preventing any accidental removal of the cutter member 14^a—18^a.

Each of the offset cutters 13^a is of preferably of hyper-conoidic form, and is provided with an elliptically rounded end rib, 20^a, similar in character to the correspondingly marked portion of the first described construction. These rounded ends engage with the boundary zone between the bottom and the completed side wall of the bore hole; but in this case the said engagement is confined to a very narrow annulus by the inward inclination of the axes and end surfaces of the rolling cutters. The duty imposed on the tooth elements of the ribs 20^a is therefore relatively light even when no complementary cutters are employed; but for the purpose of relieving these tooth elements of substantially all shearing action, I arrange the vertical spindle cutters, 14^a, in such relationship to the head that the peripheral teeth thereon roll on the parallel sides of the bore cavity and cut away the material from the path of the rotating and revolving edges 20^a, 20^a. The latter then serve only as guard elements, or as auxiliary supplemental elements, that may cooperate with the lower edge portions of the toothed cutters 14^a, when the latter become somewhat worn, or when they encounter extremely hard strata of material.

This second exemplification of my invention is also provided with devices which are adapted to feed a continuous supply of lubricant to the bearings of the revolving cutters, and which are automatically actuated and controlled by the cutter movement itself. In the form here shown this automatic feeding means comprises a small short stroke plunger pump 72 the piston of which is actuated by an eccentric pin 73 in one extension shaft collar 71. The action of the pump draws oil from the lower portion of the annular lubricant chamber—which is formed by the upper section 15^a of the head and the central water tube conduit 34^a—and

forces it into an annular groove, 74, that is covered by the flanged collar 35^a at the lower end of the said tube 34^a. The annular passage way 74 is in communication with the journal bearings of the hyper-conoidic rolling cutters 13^a through the ducts 39^a-40^a (see Fig. 6); and is also connected with the bearing surfaces of the shaft 18^a by means of the passage ways 57^a, 57^a (see Fig. 8); and the oil which is pumped into the covered groove is therefore uniformly distributed to the various cutter bearings at a rate which is determined by the relative areas of the different ducts and the angular velocity of the revolving members.

The upper surface of the mass of lubricant in the annular reservoir is covered and protected by a light piston member 41^a, which gradually descends as the oil is pumped out from the bottom of the chamber. In this construction the space above the descending piston is in open communication with the fluid which surrounds the drill head through the opening, or openings, 75. The hydrostatic pressure on the opposite ends of the lubricant column is thus normally balanced; and the action of the oil feed pump 72, is, therefore, not affected by changes, either in the absolute pressures, or in the differential pressures, of the flushing liquid inside and outside the drill stem.

The flushing liquid is carried down through the central tube 34^a, and is directed tangentially downward, on the rearward and upwardly moving sides of the rolling cutters 13^a-13^a, through the inclined passage ways 38^a-38^a. This arrangement results in the discharge of the streams of liquid at the points where their velocities are greatest with respect to the cutter surfaces on which they impinge; and thus effects a rapid and effective cleaning of the tooth elements of the skew rolling bits as they leave the material on which they are operating. The utilization of this feature of my improved construction is particularly advantageous in the case of such an organization as that last described, in which the greater part of the drilling operation is performed by two offset hyper-conoidic cutting rollers that remove the material from the bottom of the bore hole by a combined curtate-cycloidic chipping action and a side wedging or end thrust movement of their skew tooth elements; and in which there is, therefore a tendency to wedge a considerable amount of loose material into the grooves of the toothed surfaces.

Figs. 9, 10 and 11 illustrate another embodiment of my present invention, in which the drill head is, as before, preferably constructed in two sections 12^b and 15^b, that are detachably locked together by a screw joint, and are adapted to be secured to the lower end of the threaded drill stem 16^b in

the usual manner. The lower section 12^b carries two coned cutter rollers, 13^b-13^b, that are mounted on inclined stud pins 17^b, each of which is preferably made integral with a block 76 (as shown in detail in Fig. 11). These cone cutters are revolvably secured on their stud pin supports by means of the split flanged bushings 77, that are held in place in the hub of the cutters by clamp screws 78; and the block supports 76-76 are rigidly clamped in milled grooves on the opposite sides of the head by the cross bolts 24^b-24^b. The member 12^b also carries two complementary side cutting rollers 14^b-14^b, which are journaled on shafts 18^b-18^b that are inclined at a small angle to the longitudinal axis C-C of the drill. The side cutters, 14^b are housed and shrouded in suitable pockets on the periphery of the head (intermediate the milled grooves that receive the cutter block supports 76); and the lower shouldered ends of the tapered journal shafts 18^b are threaded into the end walls of these pockets. The upper cylindrical portions of the shafts are fitted closely in reamed holes which hold them rigidly against lateral displacement; and the assembled parts are locked in position both by the lower edge of the upper section 15^b-which partly covers the ends of the shaft members 18^b-and also, if desired, by fusible metal seals 33^b-33^b.

The complementary action of the two pair of rolling cutter bits, 13^b-13^b and 14^b-14^b is essentially the same as that which characterizes the previously considered exemplifications of my invention. The teeth on the sides of the rolling cone members 13^b act on the material at the center of the bore hole and cut a flat bottomed cavity whose diameter, $g-g$, is, in this case, about 70% of the finished diameter $a-a$ of the hole, and whose area is therefore about 50% of the completed section. The remainder of the material is removed from the annular zone, $a-g$, by the curtate-cycloidic action of the projecting tooth elements on the rolling surfaces of the spindle cutters 14^b-14^b. The lower extremities of these elements overlap the zone of action covered by the roller bits 13^b; and the upper ends thereof are beveled off, as at 22^b, to make an extended contact with the finished side wall of the bore hole; thus eliminating any sharp edges, or peripheral lines of rapid wear, on the cutting surfaces, and ensuring the efficient operation, and the effective maintenance of the gauge diameter, of the tool for long continued periods of drilling in hard rock formation.

The organization shown in Figs. 9 and 10 is provided with a force feed lubricating system which is actuated and controlled by the revolution of one or more of the cutter bits; and which therefore corresponds, in

functional character to the similarly actuated systems of the previously described constructions. In the third illustrative embodiment of my improvements the cutter actuated means for effecting the lubrication comprises; (1) a sleeve gear member 43^b which is detachably secured to the upper end of one of the side roller cutters 14^b (or to the adjacent extremity of the central bushing therefor); (2) an associated pinion 44^b that is attached to the lower end of the pump shaft 45^b; (3) the screw pump element 46^b which is adapted to draw liquid from the cavity in which the cutter is revolving and discharge it into the lower end of the annular opening between the upper head section, 15^b, and the central conduit 34^b; and (4) the annular piston 41^b which receives the liquid pressure established by the action of the pump 46^b and transmits it to the mass of lubricant above the said piston. The lubricant is discharged from the extreme upper end of the annular chamber in the section 15^b through an opening 80^a formed in a tube 80 that surrounds the conduit 34^b and terminates at its lower end in a recess in the section 12^b; from whence it is conducted to the bearings of the cutters 13^b by ducts 39^b—40^b (see Figs. 10 and 11), and to the journal surfaces of the cutters 14^b, by the passage ways 57^b—58^b (see Fig. 9). In this case the upper end of the annular cavity in the head is closed off from the flushing liquid by the centering plate, 81, the packing ring, 82, and the clamp nut and washer 83; but the plate 81 is provided with an aperture 84 through which the space above the piston 41^b may be filled with lubricant when the head is disconnected from the drill stem 16^b, and the packing elements 82—83 are removed.

The rate of feed to the bearings of the revolving cutters may be controlled entirely by the working pitch and the angular velocity of the screw pump 46^b; but in order to guard against an excessive or undue accumulation of pressure in the liquid filled chamber below the piston I preferably provide a spring check valve 85 which may be adjusted to open at any desired pressure and permit of the escape of a portion of this liquid to the outside of the drill head.

The flushing liquid for the various cutter members is carried down through the central conduit 34^b and is discharged from the lower end thereof through four inclined passage ways; two of which (38^b—38^b) deliver their streams against the rearward and upwardly moving sides of the cutters 13^b—13^b; while the other two (86—86) direct the issuing jets of liquid against the rearward and inwardly moving teeth of the side rolling bits 14^b—14^b. In all cases the flow is so directed that the tangential or oblique impingement of the water against the revolving cutter surfaces will effectually dislodge and wash

away the material which is chipped out by the teeth, and keep the latter in clean and effective working condition.

It will now be obvious to those skilled in this art that the general features of my invention may be embodied in a large number of different forms of boring tool construction; and that certain features of these improvements—e. g. the system of cutter controlled lubricator feed—may be employed in conjunction with horizontal and vertical disc drills, as well as with such types of roller bit tools as I have herein shown; or may be used with such associated types as are illustrated and described in my copending application Ser. No. 442,333 filed Feb. 3rd, 1921. It will be observed that my improved system of complementary cutters, comprises two sets of rolling bit members—one set of which are mounted on axes that are inclined at a large angle to the axis of rotation of the drill head and are employed to remove the material from the bottom or end of the bore cavity, and another set which are mounted in approximate parallelism to the said axis (i. e., at a small angle thereto) and are used to remove a nearly vertical portion of the side wall (i. e., the curved or tapered boundary zone between the end and the finished side of the drilled hole)—and that the maintenance of the desired “gauge” is effected by the overlapping action of both sets of rolling cutters; and it will also be apparent that this system has a wide range of application to many types of boring tools in which horizontal, or vertical, or inclined, disc cutters are used in place of either the skew roller bits or the straight roller bits herein shown. With the preceeding disclosure as a guide, engineers who are familiar with the use of these tools will be enabled to utilize my improvements in various other combinations that have not been expressly described; and I do not therefore wish to limit myself to any particular and specific exemplifications of my invention, except so far as may be indicated by the appended claims; to wit:

Claims:—

1. In a rotary boring tool, the combination of two sets of mutually complementary cutting members, one of which is provided with a toothed surface adapted to engage and remove material from the entire bottom of the bore hole, and the other one of which traverses and removes material from an annular steeply inclined zone, between the bottom and the side wall of the hole, which zone is traversed by a portion of the toothed surface of said first-mentioned member.

2. In a rotary boring tool the combination of a head, a cutter rotatably mounted thereon and provided with a toothed surface that makes rolling engagement with the entire bottom or end of the bore hole, and a second cutter rotatably mounted in approximate

parallelism with the longitudinal axis of the said head and adapted to make rolling contact with an annular steeply inclined zone between the end and the finished side wall of the said hole.

3. A rotary boring drill comprising, in combination, a head, a pair of mutually offset conoidic cutters making rolling contact with the material at the end of a bore hole, and a second pair of cutters rotatably mounted in approximately parallelism with the axis of rotation of the drill and adapted to remove a portion of the side wall of the hole.

4. A rotary boring drill comprising the combination of a head, a pair of diametrically opposed rolling cutters mounted on said head and provided with teeth for rolling on and removing material from the bottom of the bore hole, and a second pair of diametrically opposed rolling cutters mounted on said head and spaced between the first pair, and provided with teeth located at an angle to the teeth of said first-mentioned pair for removing material from a zone between the end and the finished side wall of hole which zone is traversed alternately by a portion of the toothed surface of both pair of cutters.

5. In a rotary boring tool, the combination of a head, a cutter rotatively mounted on said head and having an effective cutting surface extending at an angle to the axis of rotation of the head, and a second cutter mounted on said head having an effective cutting surface extending in substantial parallelism with the axis of rotation of the head, said cutters adapted to alternately traverse and remove material from an annular steeply inclined zone between the bottom of the hole and the finished side wall thereof.

6. In a rotary boring tool, the combination of a head, a rolling cutter supported thereon having a longitudinally toothed portion and a transversely toothed portion, a second rolling cutter mounted on said head and having a longitudinally toothed portion located approximately at right angles to the longitudinally toothed portion of the first cutter and adapted to alternate with the transversely toothed portion of said first cutter in removing material from the path traversed by the transversely toothed portion of said first cutter.

7. In a rotary boring tool, the combination of a head and two groups of rolling cutters supported thereon with the rolling surfaces of one group approximately at right angles to those of the other, the cutters

of one group being provided with a transversely toothed end portion and the cutters of the other group having longitudinally toothed surfaces which roll on and remove material from the path traversed by said transversely toothed portions of the cutters of the other group.

8. In a rotary boring tool, the combination of a head, a plurality of cutters mounted thereon, a lubricant chamber, a piston within the chamber, ducts leading from said chamber to bearings of said cutters, and an enclosed and protected reduction gearing between one of said cutters and said piston comprising intermeshing gears, a worm wheel and screw so associated as to produce a very slow longitudinal movement relatively to the rotation of said cutter.

9. In a rotary boring tool, the combination of a head provided with a lubricant chamber, a plurality of cutters mounted on the head, ducts leading from said chamber to bearings of said cutters, means within said head for forcing lubricant therefrom through said ducts, and gearing enclosed within said head, actuated by one of said cutters, and operatively connected to said means.

10. In a rotary boring tool, the combination with a head having a lubricant chamber formed therein, and ducts leading therefrom to cutter bearings, a plurality of cutters mounted on said head, means for forcing lubricant from said chamber through said ducts, and a reduction gearing located wholly within said head, actuated by one of said cutters and operatively connected to said means.

11. In a rotary drilling tool the combination of a head, a revolvable cutter member provided with a toothed surface adapted to make rolling engagement with the bottom of the drill hole and with an elliptically rounded end portion adapted to make cutting contact with the outer boundary zone of said bottom, a second cutter member revolvably mounted on an axis approximately parallel to the axis of rotation of the drill head and provided with a toothed surface engaging at one end with the boundary zone traversed by the rounded extremity of the first cutter member and at the other end with the completed side wall of the drill hole, and means actuated by the rotation of the drill head or its movable members for supplying lubricant to the bearings of the said members.

In testimony whereof I have hereunto set my hand.

FRANK L. O. WADSWORTH.