Dec. 29, 1964 J. M. CLEARY 3,163,243

UNDERDRILLING BIT

Filed Dec. 30, 1960 4 Sheets-Sheet 1

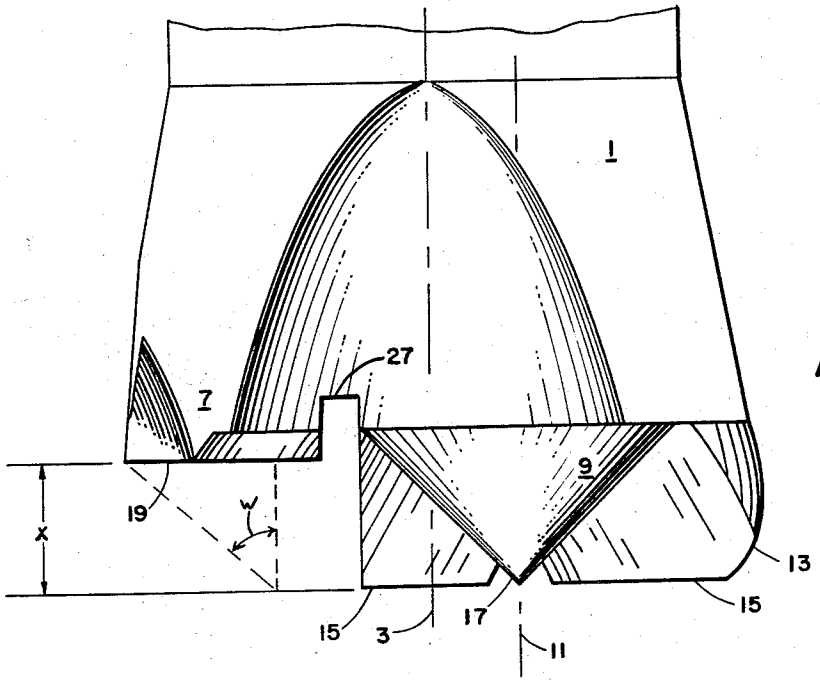

Fig. 1

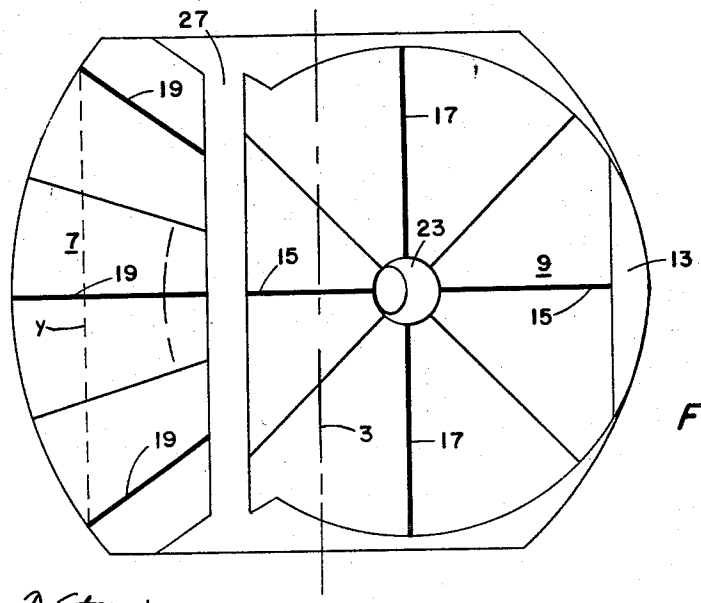

Fig. 2

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UNDERDRILLING BIT

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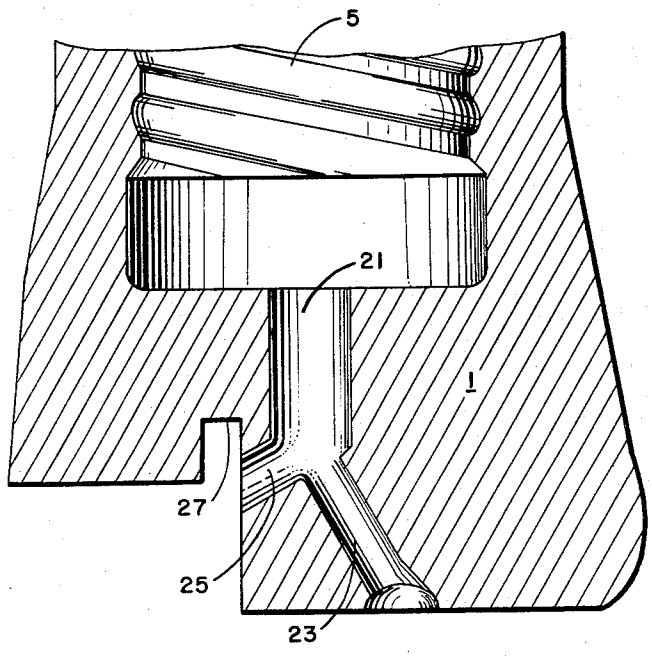

Fig. 3

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UNDERDRILLING BIT

Filed Dec. 30, 1960 4 Sheets-Sheet 3

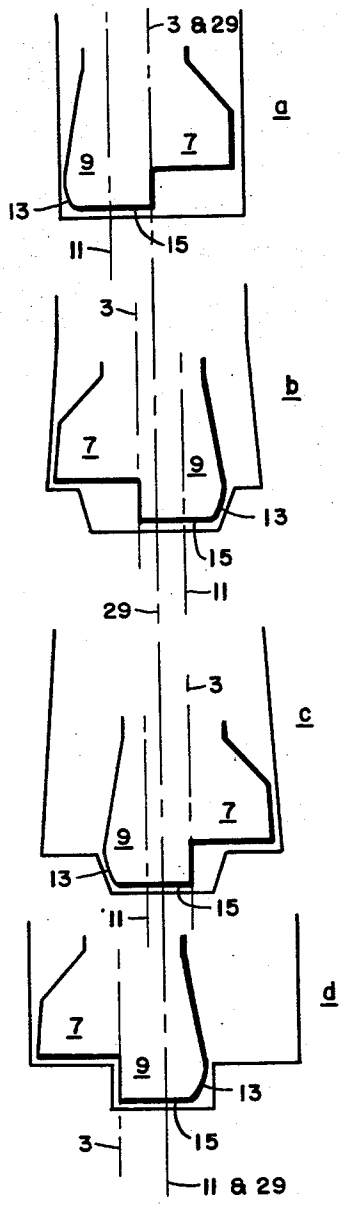

Fig. 4

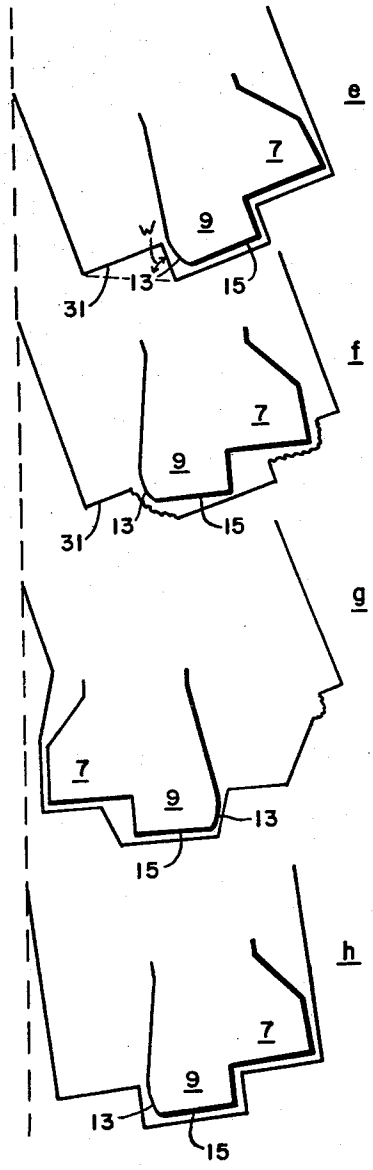

Fig. 5

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Filed Dec. 30, 1960 4 Sheets-Sheet 4

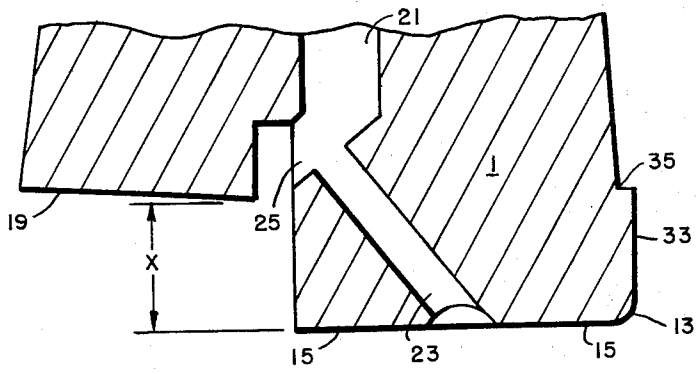

Fig. 6

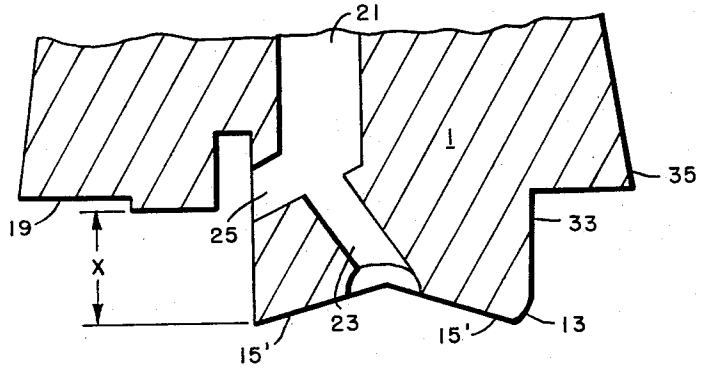

Fig. 7

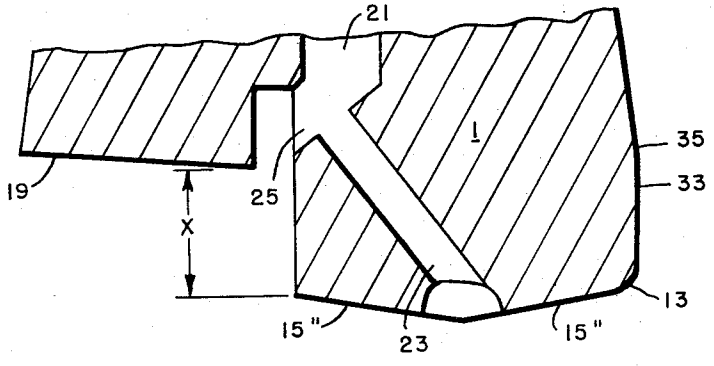

Fig. 8

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3,163,243

UNDERDRILLING BIT

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7 Claims. (Cl. 175—389)

The present invention relates to an improved apparatus for drilling a borehole in the earth. In a more particular aspect, the present invention relates to improved bits for maintaining a vertically straight borehole or straightening a borehole which has deviated from vertical.

In the art of drilling boreholes in the earth for the production of oil and gas, a major problem encountered in present-day operations is the unintentional deviation of the borehole from the vertical. In present-day operations, irrespective of the type of drilling bit employed, bending of the drill pipe supporting the bit, the striking of discontinuities in the formations traversed and uneven wear of the cutting surfaces of the bit itself tend to cause the borehole to deviate from vertical. Since a small deviation eventually becomes quite large as the depth of the borehole increases, such deviation can in many cases result in the driller completely missing his drilling target and, in most cases, makes it difficult to place production equipment in such deviated boreholes. It is, therefore, necessary in present-day drilling operations to intermittently interrupt the drilling in order to straighten the borehole and bring it back to vertical. Such straightening operations require the use of additional equipment and usually involve the removal of the bit from the well. If such removal of the bit from the well and straightening of the well bore could be carried out only when it was necessary to replace a worn or broken bit, the problem would not be so serious. However, it is a rare occasion when straightening of the borehole can be coordinated with removal and replacement of the bit. Accordingly, deviation of a borehole from vertical becomes a serious detriment to drilling operations, and the straightening of the borehole adds considerably to the cost of the operation. It would, therefore, be highly desirable to provide a simple and economic method of straightening a deviated borehole without additional equipment and without the necessity of removing the bit from the hole.

When a borehole is drilled it usually tapers slightly during a single bit run due to gage wear on the bit. Sometimes this taper presents the problem of reaming a new bit to bottom. This necessity to ream results in an extra expenditure of rig time and extra bit wear. Alternatively, it may be necessary to make each new bit smaller than the previous bit. Also, on occasion a buildup of cuttings or a combination of mud cake and cuttings on the sides of the hole wedge and stick the bit as it is pulled from the hole. This difficulty is most common in air or gas drilling when a small amount of moisture is present in the hole. It would, therefore, be advantageous if a bit could be employed which would drill a hole substantially larger than the diameter of the bit itself.

Finally, in many drilling operation, it would be highly desirable if casing could be set in the hole as the drilling of the hole progresses rather than after the entire hole has been drilled. With present-day bits, it is wholly impractical to case a hole while the drilling operation progresses since the vast majority of present-day bits drill a hole substantially equal to the bit diameter and, if the casing were set during drilling, it would be necessary to remove the casing from the hole each time it is necessary to replace the drill bit. It would, therefore, be advantageous to provide a drill bit small enough to pass through the interior of the well casing but which would

drill a hole sufficiently large to permit setting of the casing in the hole while the drilling operation progressed.

It is an object of the present invention to provide an improved drill bit adapted to straighten a deviated borehole.

A further object of the present invention is to provide an improved drill bit which is adapted to maintain a borehole vertical during the progress of the drilling operation.

A further object of the present invention is to provide an improved drill bit adapted to drill a borehole substantially larger than the diameter of the bit itself.

Still another object of the present invention is to provide an improved drill bit capable of underdrilling beneath a casing but movable through the interior of the casing.

Other and further objects of the present invention will be apparent from the following detailed description when read in conjunction with the drawings.

In the drawings:

FIGURE 1 is an elevational view of a rotary percussion bit in accordance with the present invention.

FIGURE 2 is a plan view of the rotary percussion bit of FIGURE 1.

FIGURE 3 is an elevational view in section of the rotary percussion bit of FIGURE 1.

FIGURE 4 illustrates the manner in which the rotary percussion bit of FIGURE 1 functions to drill a borehole substantially larger than the diameter of the bit itself.

FIGURE 5 illustrates successive steps in the straightening of a deviated borehole with the rotary percussion bit of FIGURE 1.

FIGURES 6, 7 and 8 are fragmented elevational views in section of the rotary percussive drilling bit showing three different locations of the pilot portion on the bit body, different slopes for the cutting edges and illustrating the distance "x" by which the pilot cutters lead the gage cutters.

In accordance with the present invention, it has been found that a deviated borehole can be returned to vertical or a borehole can be maintained vertical by utilizing a rotary percussion bit having certain critical design features. Briefly, the improved bit of the present invention comprises a rotary percussion bit having a main body portion carrying gage cutting teeth and a pilot portion, leading the gage cutting teeth, which has a central axis offset from the axis of the main bit body, cutting teeth extending in a horizontal plane across at least half of the pilot portion and a noncutting surface formed on that side or peripheral half of the pilot portion which is furthest from the cenrtal axis of the main bit body. The subject bit tends to drill a central pilot hole and the gage cutting portion of the bit then sweeps about the central axis of the pilot portion to cut a borehole whose diameter is equal to twice the distance from the central axis of the pilot to the furthermost tip of the gage cutting portion. In order to straighten a deviated borehole or maintain the borehole vertical, the drilling operation is interrupted, the bit is lowered and vertically vibrated to destroy the shoulder formed by the offset gage cutters on the low side of the hole and rotation of the bit is resumed to drill a new pilot and a new borehole whose axis of inclination is closer to vertical. This procedure can be repeated as often as necessary to straighten the deviated hole and return it to vertical or to maintain the borehole vertical.

In rotary percussion drilling, the drill bit is vibrated in a vertical direction while rotating the bit. The vertical vibration of such a bit is the main drilling force and tends to chip away portions of the formation immediately beneath the cutting teeth and as the bit rotates this chipping action covers the entire bottom of the bore-

hole. In the standard form of percussion bit, the teeth consist of substantially V-shaped cutters radiating from the central axis of the bit and all such cutters are located on the same horizontal plane. Obviously, a bit of this design will drill a borehole substantially equal to the diameter of the bit itself.

The improved rotary percussion bit of the present invention is illustrated in detail in FIGURES 1, 2 and 3 of the drawings. In accordance with said figures, a main bit body **1** having a central axis **3** is provided with an internally threaded bore **5** for attachment to the lower end of a tubular drill string (not shown). Although a connection for a tubular drill string is shown for simplicity, a fluid driven percussion unit is usually mounted in this position adjacent the bit. The main bit body **1** is divided into two portions; namely, a gage cutting portion **7** and a pilot cutting portion **9**. Pilot cutting portion **9** leads gage cutting portion **7** in the direction of bit penetration and the axis **11** of pilot cutting portion **9** is offset from central axis **3** of the main bit body. Pilot cutting portion **9** has formed on the side most remote from the central axis **3** of the main bit body a noncutting surface **13** which is a surface sloping inwardly toward the center of the bit and forwardly with relation to the direction of the main cutting force and, therefore, presents a noncutting surface in the direction of the main cutting force of the bit. As will be explained in more detail hereinafter, noncutting surface **13** causes the pilot to drift inwardly toward the center of the hole and ultimately drill a hole with central axis **11** of pilot portion **9** disposed on the central axis of the borehole and gage cutting portion **7** sweeping about axis **11** of the pilot portion. Pilot portion **9** is provided with a plurality of V-shaped cutting elements **15** and **17** diametrically crossing the bottom face thereof. As FIGURE 2 of the drawings clearly illustrates, cutting element **17** of pilot portion **9** is adapted to describe a cylindrical pattern whose radius is equal to the radial distance from the central axis **11** of pilot portion **9** to the furthest extremity of noncutting surface **13**. The reason for thus selecting the length of cutting element **17** will hereinafter be explained. The necessity of having cutting element **15** extend across the center of pilot portion **9** on that side of said pilot portion which carries noncutting surface **13** will also be explained later.

Gage cutting portion **7**, as previously indicated, is above and trails pilot cutting portion **9** with relation to the direction of bit penetration. Accordingly, gage cutting portion **7** forms a second substantially horizontal plane across the body of the bit. Gage cutting portion **7** is provided with a plurality of V-shaped teeth **19** which are radially disposed on gage cutting portion **7** with central axis **11** of pilot portion **9** as the center of such radii. Other centers may also be used.

It should be recognized that a plurality of short V-shaped teeth or a plurality of button-type percussive cutters may be substituted for the elongated, V-shaped cutters of gage cutting portion **7** and pilot cutting portion **9**.

In order to provide for the removal of formation cuttings from beneath the bit, a suitable drilling fluid is circulated through the tubular drill string which supports the bit and is distributed beneath the bit and returned to the surface of the earth through the annular space surrounding the bit body and the tubular drill string. As shown in particular in FIGURE 3 of the drawings, the drilling fluid after leaving the drill string passes through channel **21** centrally located in the body of the bit and thence through branch channels **23** and **25**. Drilling fluid issuing from branch channel **25** is dispersed across the base of pilot cutting portion **9** through the V-shaped channels between cutting teeth **15** and **17** to thereby continuously remove cuttings from beneath pilot portion **9** of the bit. Drilling fluid emanating from branch channel **23** passes across the surface of gage cutting portion **7** through the V-shaped channels between teeth **19** and also through groove **27** chordally crossing the bit body between gage cutting portion **7** and pilot cutting portion **9**.

The distance x which is shown in FIGURES 1, 6, 7 and 8 and by which pilot portion **9** leads gage cutting portion **7**, is extremely important to the operation of the subject bit. As shown, the distance x is the distance that the uppermost tip of the pilot cutting edge or edges near the walls of the pilot hole drilled by the pilot portion of the bit lead the lowermost part of the cutting edge or edges of the gage cutting portion. If the distance x is too small, pilot portion **9** will fail to drill a pilot hole of sufficient depth to stabilize the bit and the bit will have a tendency to drill a hole approximately the same size as the diameter of the bit. Accordingly, it has been found that, in order to drill a pilot hole of sufficient depth to eventually stabilize the bit and then drill a hole substantially larger than the diameter of the bit, the distance x by which pilot portion **9** leads gage cutting portion **7** should be at least 0.15 times the diameter of the bit. With a pilot of sufficient length, the bit will become stabilized and drill a hole substantially larger than the diameter of the bit as set forth in the prior discussion. It should also be recognized that there is a maximum distance x by which the pilot portion leads the gage cutting portion. This maximum distance is dictated to some extent by the use to which the bit is to be put. However, in any event, the ratio of the distance x to the bit diameter should not exceed about 1.25. This maximum limit is based on strength considerations including the strength of the pilot itself and the connection of the bit to the percussion unit. In addition, if the bit is to be employed to maintain a borehole vertical or straighten a deviated borehole, the distance x should be as close to the minimum (0.15) as possible. The criteria for determining the maximum ratio of the length of the pilot to the diameter of the bit are expressed below. The ratio of the lead of the pilot to the diameter of the main bit may be expressed by the formula:

$$R=\frac{x}{d_2}$$

where

R=ratio
x=length of pilot, and
d_2=diameter of bit

In order to destroy shoulder **31** of FIGURE 5 by percussive action one must take into consideration the compressive sheer angle of the formation being drilled. The average sheer angle for most formations encountered is about 28 degrees. Therefore, in order to destroy shoulder **31** (view *e* of FIGURE 5) by percussive action, the angle w of shoulder **31** (applied to the bit of FIGURE 1), must be larger than about 28 degrees. Observation of FIGURE 1 shows that angle w is related to the diameter of the bit, the diameter of the pilot and the length of the pilot. The following expression can therefore be written:

$$\tan w=\frac{d_2-d_1}{x}$$

where d_1=diameter of the pilot.
Then:

$$x=\frac{d_2-d_1}{\tan w}$$

and since,

$$R=\frac{x}{d_2}$$

then

$$R=\frac{1-d_1/d_2}{\tan w}$$

For example, in the bit shown in FIGURES 1 to 3 of the drawings, w is 48 degrees and $R=.235$. For bits having this same ratio of bit diameter to pilot diameter the maximum ratio (where w is 28 degrees) should be $R=0.47$. Other bits may, of course, have different ratios of the diameter of the pilot to the diameter of the bit, depending upon the hole enlargement desired; but, as previously stated, it has been found that a practical upper limit is $R=1.25$.

It should be recognized that the number of cutters on both pilot cutting portion **9** and gage cutting portion **7** may be reduced. Specifically, a single cutter across the middle of gage cutting portion **7** may be substituted for the three cutters **19** shown in the drawings. Similarly, cutter **17** may be eliminated from pilot portion **9** leaving a single cutter **15** across the middle of pilot portion **9**. In this case, the length of cutter **15** should be increased toward the center of the bit so that the interior tip of cutter **15** will cut a hole whose circumference includes the furthest extension of noncutting surface **13**. In order to simplify the following discussion of the operation of the bit of the present invention, it will be assumed that the bit is provided with a single gage cutter on gage cutting portion **7** and a single relief cutter **15** on pilot portion **9** as described immediately above.

As has been pointed out above, a single cutter may be utilized on gage cutting portion **7** rather than a plurality of cutters **19**. However, a single gage cutter is seriously limited in use in that a bit with a single gage cutter will have a substantially lower rate of penetration, will wear more rapidly and need replacement more frequently and will be inefficient in many respects. Accordingly, two or more gage cutters should be employed in accordance with the present invention. If two or more cutters are mounted on gage cutting portion **7**, certain critical design features enter the picture. Since one of the basic objectives of the present invention is to provide a bit which will pass through a comparatively small hole, such as a casing, and drill a substantially larger hole, the amount or percent of hole enlargement obtained over the size of the bit itself becomes extremely important. The greatest percent of hole enlargement over bit size will be obtained when a single gage cutter is used and the peripheral cutting point of this cutter and the outermost peripheral point of noncutting surface **13** are separated by 180 degrees. However, as previously pointed out, a bit with a single gage cutter is seriously limited. It has been found that the spread of angle between the tips of the outermost gage cutters of the bit should be below a certain critical limit when two or more gage cutters are employed. This limit, as applied to all bits, irrespective of the size of the pilot portion, the location of the central axis of the pilot or the location of the point from which the gage cutters radiate, is best expressed by a comparison of the distance between the tips of the two outermost gage cutters (y of FIGURE 2) and the diameter of the bit. In accordance with the present invention, the ratio of the distance y to the diameter of the bit should be less than 0.95. Where the bit is to be employed to underdrill below a casing, this ratio should preferably be below 0.80. By utilizing this criteria in the design of the bit, the percent hole enlargement will be substantial; while for a larger ratio (a larger ratio than 0.95) the percent hole enlargement will be almost negligible. Depending upon the distance y, it may be desirable to add gage cutters between the two cutters referred to. However, this depends upon whether the cutters can be spaced a sufficient distance apart to permit removal of cuttings and prevent clogging of the bit.

In order to give a specific example of the application of this principle, reference is made to FIGURE 2. In FIGURE 2, the difference between the diameter of the bit and the diameter of the hole it will drill divided by the diameter of the bit gives a hole enlargement of about 25 percent. To underdrill below a casing, the enlargement for this purpose should be greater than about 30 percent. Thus, although useful for other purposes, this bit should not be used to underdrill below a casing. The ratio of the distance y between the tips of the outermost cutters over the dimeter of the bit is about 0.70. Since cutters **19** radiate from the central axis of the pilot portion **9** of the bit, the outermost gage cutters form an angle of about 70 degrees. However, this angle would change if the point from which cutters **19** radiate were moved inwardly or outwardly. Accordingly, the ratio of the distance y to the diameter of the bit is a better criteria than the angle between the gage cutters. However, in general, all bits designed within the minimum set forth above (ratio of 0.95) will have an angle between the cutters of less than about 120 degrees and when designed within the preferred limit (ratio of 0.80) this angle will be less than about 90 degrees.

A related factor, which also bears on the percent of hole enlargement which can be attained, is the comparative diameter of the over-all bit and the diameter of the pilot. Since gage cutting portion **7** of the bit sweeps about axis **11** of pilot **9**, when the bit becomes stabilized, the ultimate gage of the hole will depend upon the ratio of the bit diameter to the pilot diameter. If this ratio is 1.0, the bit obviously will not drill an enlarged hole; and, the larger this ratio the greater will be the percent hole enlargement. However, a pilot which is too small as compared with the over-all bit will be too weak to function properly or will tend to wear unevenly or break frequently. Accordingly, it has been found that, as a practical matter, the ratio of the diameter of the bit to the diameter of the pilot should not exceed about 3. Further, to underdrill below a casing, this ratio should be above about 1.3.

As illustrated in FIGURES 6, 7 and 8 outer pilot side **33** or the outer periphery of the pilot where noncutting surface **13** terminates does not need to be coincident with outer bit side **35** or the periphery of the main bit. In FIGURE 6, outer pilot side **33** extends beyond outer bit side **35**. In FIGURE 7, outer bit side **35** extends beyond outer pilot side **33** and in FIGURE 8, the outer sides meet at a coincident point.

Although the outer periphery of the pilot need not be coincident with the outer periphery of the main bit, good design dictates that such coincidence be present.

Finally, in order to achieve maximum cutting efficiency, the gage cutters should preferably radiate from the axis of the pilot since this is the axis about which the entire bit rotates when it reaches its stabilized position.

In order to understand the manner in which the bit of the present invention operates to straighten a deviated borehole, it is first necessary to describe how the subject bit functions to drill a borehole substantially larger than the diameter of the bit itself. This operation is illustrated in FIGURE 4 of the drawings.

In FIGURE 4 view *a* shows the bit disposed in a borehole substantially equal to the diameter of the bit before the drilling operation is begun. The borehole in this case has a central axis **29** which coincides with central axis **3** of the main bit body. Central axis **11** of pilot portion **9** is at this stage offset from central axis **29** of the borehole. View *b* shows the condition of the borehole and the new position of the bit after the bit has been vibrated and rotated for some time. In view *b*, the central axis of the bit **3** has moved off the axis **29** of the borehole, and axis **11** of pilot portion **9** has moved closer to axis **29** of the borehole due to the inward thrust applied to the pilot by noncutting surface **13**. Also, in view *b*, pilot portion **9** has begun to drill a pilot hole which at this stage is larger in diameter than the pilot, and gage cutting portion **7** has begun to enlarge the hole due to the fact that axis **3** of the bit has shifted from axis **29** of the borehole and is now sweeping about axis **29**. View *c* shows a still further stage in the drilling of the hole in which axis **3** of the bit has moved further

from central axis 29 of the borehole and axis 11 of pilot portion 9 has moved closer to borehole axis 29. At this point in the operation, noncutting surface 13 has continued its inward thrust of the pilot portion 9, the pilot hole being drilled by pilot portion 9 has a smaller diameter more closely approaching the diameter of pilot portion 9, and gage cutting portion 7 has further enlarged the over-all diameter of the hole. Finally, in view *d*, the bit has become stabilized in the borehole, axis 3 of the bit has moved further from axis 29 of the borehole, and axis 11 of pilot portion 9 now coincides with central axis 29 of the borehole. This condition is brought about by the fact that noncutting surface 13 has continued to displace pilot portion 9 inwardly toward the center of the hole until cutter 15 cuts relief for noncutting surface 13. The pilot hole is now substantially equal in diameter to the diameter of pilot portion 9 and, since the innermost point of cutter 15 is cutting a cylinder whose circumference includes the outermost edge of noncutting surface 13, the force previously being applied by noncutting surface 13 no longer causes the pilot to drift inwardly. Accordingly, the bit has become stabilized in the positon shown and will thereafter continue to rotate about axis 11 of pilot portion 9. Gage cutting portion 7 is now cutting the ultimate gage of the borehole and the ultimate diameter of the borehole is equal to twice the distance from axis 11 of pilot portion 9 to the outermost tip of the cutters of gage cutting portion 7. Thus, it is to be seen, from the illustration, that after a short distance of penetration the bit has enlarged a hole which was substantially equal to the bit diameter by as much as 50 percent. It will be obvious from the above-described operation that the amount which the bit will enlarge the hole is dependent upon the distance by which the central axis 11 of pilot portion 9 is offset from the central axis 3 of the bit. As previously indicated, it should also be recognized that pilot portion 9 need not be coincident with the outer periphery of the main bit body since it will still operate to force the bit to drift inwardly and ultimately drill a larger hole so long as its axis is offset from the axis of the main bit body and it is provided with noncutting surface 13 and relief cutter 15.

The bit of the present invention is particularly useful in maintaining a borehole vertical or straightening a deviated borehole which has drifted from vertical. In either case, the straightening operation is substantially the same except that where a hole is to be maintained vertical, the operation is carried out at frequent intervals irrespective of any known deviation of the hole. This straightening operation involves stopping the vibratory and rotary motion of the bit, lifting the bit from the bottom of the hole, dropping the bit back on the bottom of the hole, vibrating the bit without rotation and then resuming the vibratory and rotary motion of the bit. The manner in which this operation straightens a deviated borehole is illustrated in FIGURE 5 of the drawings. View *e* of FIGURE 5 shows the bit in a stabilized position similar to that of view *d* of FIGURE 4, in which position it is drilling a hole substantially larger than the bit itself. However, in this case, the hole is inclined from the vertical. The inclination of the borehole as shown in view *e* and the amount by which a single straightening operation changes the axis of the hole have been exaggerated in order to more clearly illustrate the operation. In view *e*, it is first noted that the bit is drilling a hole having a shoulder 31 formed on the low side of the hole closest to the original vertical axis of the hole. In order to straighten the borehole, it is first necessary that shoulder 31 be wholly or partially destroyed. This is accomplished by discontinuing the vibratory and rotary motion of the bit, lifting the bit from the bottom of the borehole, dropping the bit back on the bottom of the borehole and vibrating the bit without rotating. When the bit is dropped back to the bottom of the borehole, gravity and the weight of the bit and its supporting drill string will cause the bit to hit on the low side of the hole. If pilot portion 9 of the bit drops on shoulder 31 and is vibrated in this position, it will destroy a portion of shoulder 31 as shown in view *f*. As previously implied, where a borehole is to be maintained vertical by this operation, it is left to chance whether pilot portion 9 drops on shoulder 31 or at some other position in the hole. If pilot portion 9 does drop on shoulder 31, it will then destroy shoulder 31 and proceed to straighten the hole as will be hereinafter explained. On the other hand, if pilot portion 9 does not drop on shoulder 31 on the low side of the hole, the pilot will tend to ren-enter the original pilot hole and when drilling is resumed will simply continue drilling the hole at its original inclination. However, it is obvious that if the operation of lifting the bit and then dropping it is repeated at sufficiently frequent intervals during the drilling operation, pilot portion 9 will drop on shoulder 31 on the low side of the hole a sufficient number of times to straighten any slight inclination of the hole and thus maintain the hole vertical.

After shoulder 31 on the low side of the hole has been partially destroyed as shown in view *f*, the rotary motion of the bit is resumed. View *g* shows the condition of the hole after the vibratory and rotary motion has proceeded for some time. The stage of the progress of the drilling operation shown in view *g* is approximately the same as that shown in view *c* of FIGURE 4. In view *g*, pilot portion 9 has begun to drill a pilot hole displaced from the original pilot hole in the vicinity of the bottom of the hole where shoulder 31 was destroyed. Because of the force applied by noncutting surface 13, pilot portion 9 begins to drift in toward the center of the new pilot hole and gage cutting portion 7 of the bit begins to cut into the low side of the main borehole. Finally, after continued vibratory and rotary motion, the bit again reaches a stabilized position, as shown in view *h*, when relief cutter 15 begins to cut relief for noncutting surface 13. In this position, the pilot hole is substantially equal to the diameter of pilot portion 9, the central axis of pilot portion 9 is the central axis of the new pilot hole and the new borehole, and gage cutting portion 7 is sweeping around the central axis of pilot portion 9. View *h* is, of course, illustrating a condition equivalent to that of view *d* of FIGURE 4 where the bit has reached its final stabilized position and will continue to drill a hole in this position. However, the hole being drilled in view *h* is still inclined slightly from the vertical. Accordingly, the straightening operation should be repeated until the hole is again vertical.

Where a deviated hole is to be straightened by the method set forth herein, the orientation of pilot portion 9 can be predetermined to assure destroying shoulder 31. This can be done at periodic intervals when the inclination of the borehole reaches an undesirable maximum as measured by conventional inclinometers, etc. The inclination of the hole may be measured each time the bit is removed for replacement or other purposes. Having determined that the hole is inclined from the vertical, the bit may be oriented so that pilot portion 9 will be turned toward the low side of the hole and then dropped to the bottom in this position so that pilot portion 9 will destroy shoulder 31 on the low side of the hole when vibratory action is begun. Selective orientation of pilot portion 9 can also be used to drill an inclined hole having a different direction of inclination than the original inclination.

As previously indicated, it is essential that cutter 15 extend beyond the center of pilot portion 9 in the direction of noncutting surface 13. If cutter 15 does not extend beyond the center of the pilot portion and, in fact, does not extend across substantially the entire face of pilot portion 9, the bit will not destroy shoulder 31 and will not operate to straighten a deviated borehole as described above. Stated differently, if noncutting surface 13 extends to the center of the pilot portion or beyond, pilot portion 9 will simply slide off shoulder 31 and back

into the original pilot hole, the shoulder will not be destroyed and a new pilot hole will not be drilled in order to straighten the hole. It is also obvious from what has been said above that the cutters of the pilot portion should be substantially horizontal as shown in FIGURES 1 and 6, or inclined upwardly and inwardly toward the center of the bit, as shown in FIGURE 7, in order to be useful in straightening the borehole. If the cutters of pilot portion 9 are inclined upwardly and outwardly from the center by more than a small angle, illustrated in FIGURE 8, the bit will again tend to slide off shoulder 31 and back into the same hole it was previously drilling.

It will be obvious to one skilled in the art that variations and modifications other than those specifically set forth above may be practiced without departing from the invention of the present application. Accordingly, obvious modifications and variations are to be included and the present invention is to be limited only by the following claims.

I claim:

1. An improved rotary percussion bit for drilling boreholes in the earth comprising a main bit body, rotary pilot drilling means on the bottom of said bit body whose cross section is smaller than said bit body, whose central axis is offset from the central axis of said bit body and which terminates in a generally flat, horizontal surface, a noncutting surface formed on the lower end at the side of said rotary pilot drilling means furthest from said axis of said bit body, said noncutting surface sloping inwardly toward the axis of the bit body and forwardly with respect to the direction of penetration of said bit and adapted to force said rotary pilot drilling means inwardly toward said axis of said bit body, at least one first rotary percussive cutting means located on that half of said pilot drilling means nearest the central axis of said bit body extending from adjacent the axis of said pilot means to the inner edge of the said pilot means and adapted to cut a cylindrical pilot hole with substantially vertical sides whose circumference accommodates the outer most extension of said noncutting surface when said axis of said rotary pilot drilling means coincides with the central axis of said borehole, at least one second rotary percussive cutting means located on that half of said pilot drilling means furthest from the central axis of said bit body, third rotary percussive cutting means on the bottom surface of said bit body above said rotary pilot drilling means and having at least one cutting edge adapted to cut an annular section of the earth immediately surrounding said pilot hole and trailing said pilot hole with respect to the direction of penetration of said bit, and said first and second percussive cutting means on said pilot drilling means leads said third percussive cutting means on said main bit body by a distance between 0.15 and 1.25 times the maximum width of said bit body.

2. A bit in accordance with claim 1 wherein the outermost part of the rotary pilot drilling means furthest from the axis of the bit body is coincident with the outer side of said bit body.

3. A bit in accordance with claim 1 wherein the outermost part of the rotary pilot drilling means furthest from the axis of the bit body extends beyond the outer side of said bit body.

4. A bit in accordance with claim 1 wherein the width of the bit body is between 1.3 and 3.0 times as great as the width of the rotary pilot drilling means.

5. A bit in accordance with claim 1 wherein the first rotary percussive cutting means and the second rotary percussive means are one elongated generally V-shaped cutter.

6. A bit in accordance with claim 1 wherein the first and second rotary percussive cutting means are substantially horizontal.

7. A bit in accordance with claim 1 wherein the first and second rotary percussive cutting means slope upwardly and inwardly toward the axis of the bit body.

References Cited in the file of this patent

UNITED STATES PATENTS

335,373	Marcy	Feb. 2, 1886
773,962	McCray et al.	Nov. 1, 1904
1,218,671	Lane	Mar. 13, 1917
1,248,614	Chapman	Dec. 4, 1917
2,342,498	Spang	Feb. 22, 1944

FOREIGN PATENTS

28,328	Austria	Jan. 15, 1906
179,586	Germany	Dec. 7, 1906
472,053	Germany	Feb. 28, 1929