Dec. 26, 1961

J. B. STEEN

3,014,544

JET ROCK BIT

Filed July 22, 1959

3 Sheets-Sheet 1

Fig. 3.

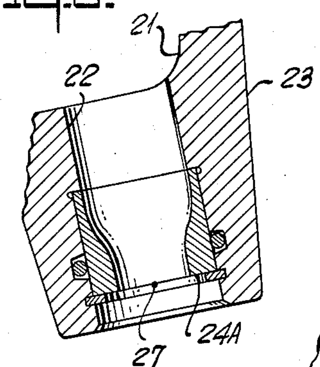

Fig. 1.

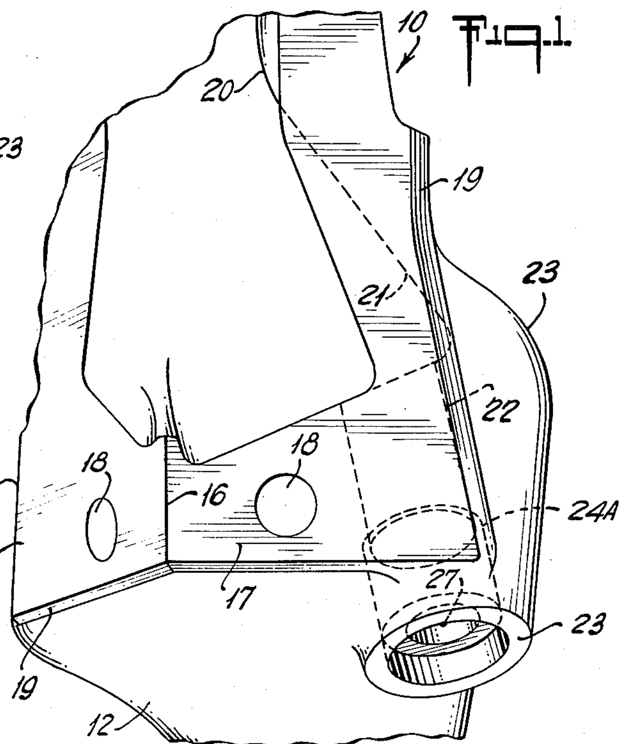

Fig. 2.

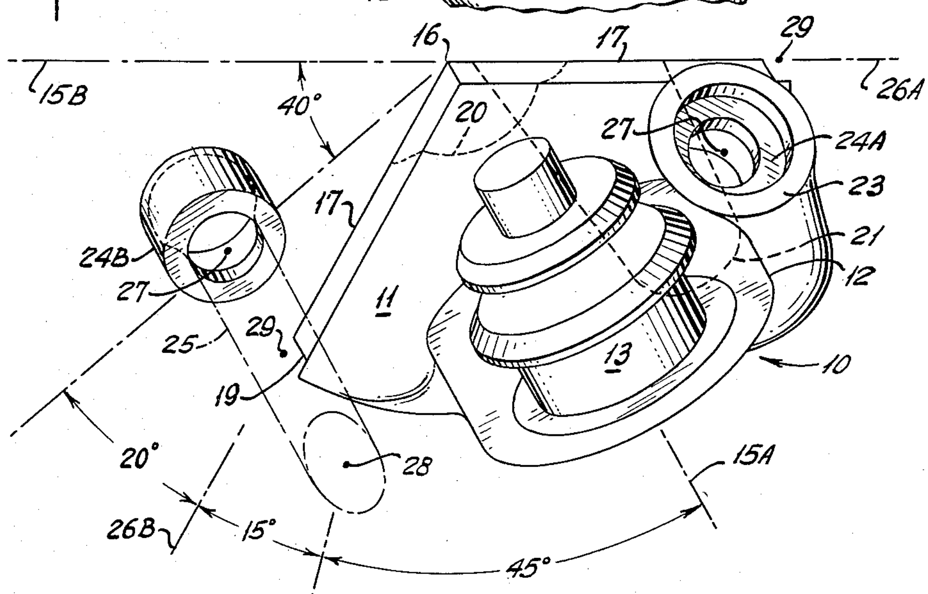

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Fig. 4.

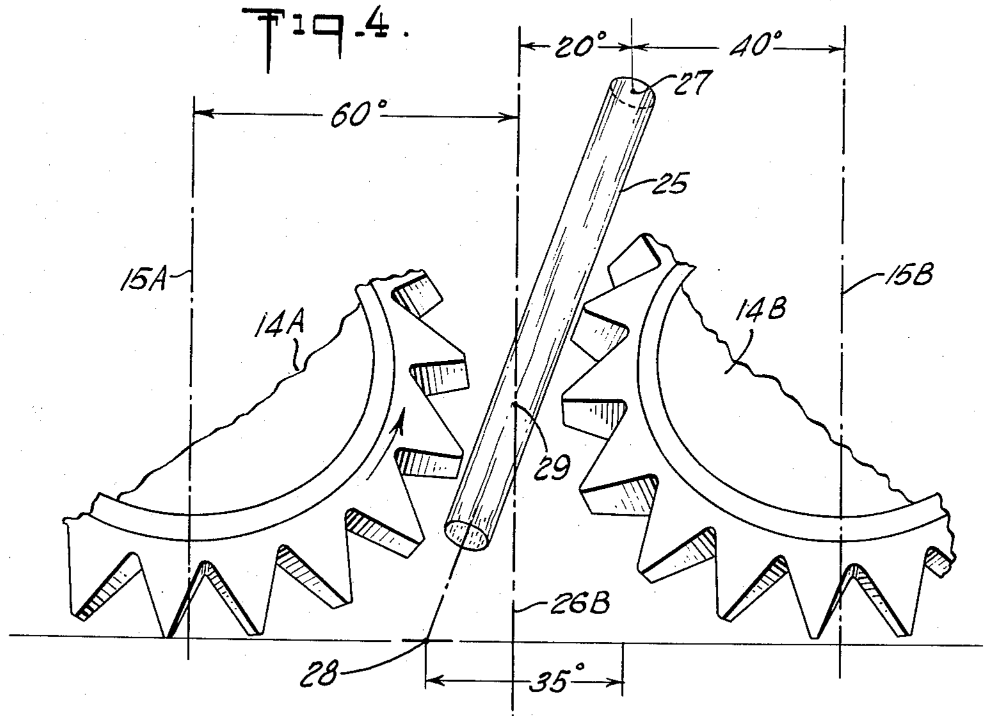


Fig. 5.

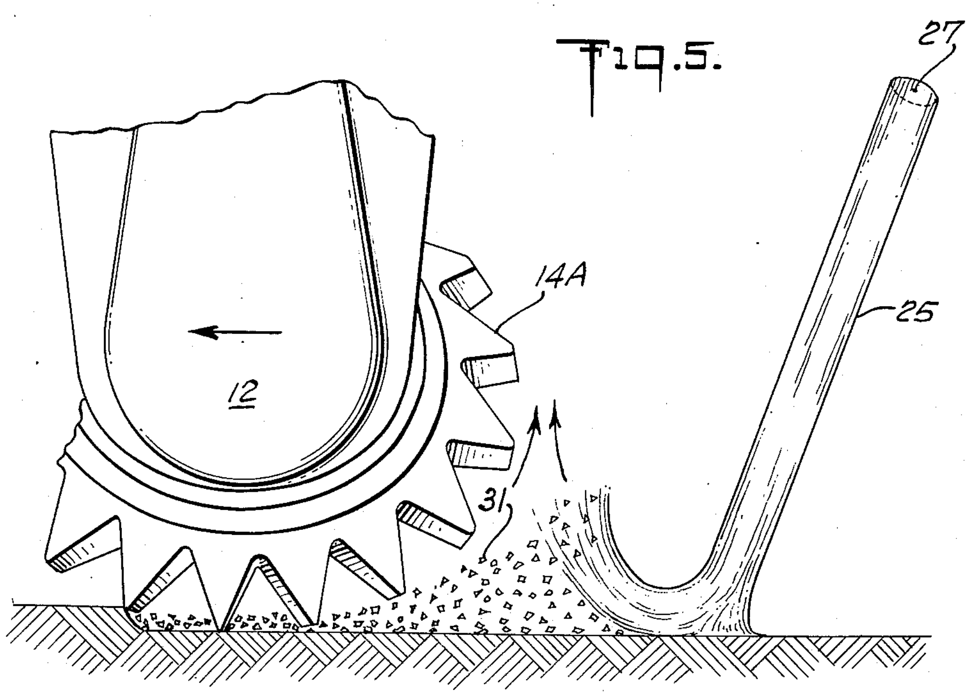


FIG. 6.

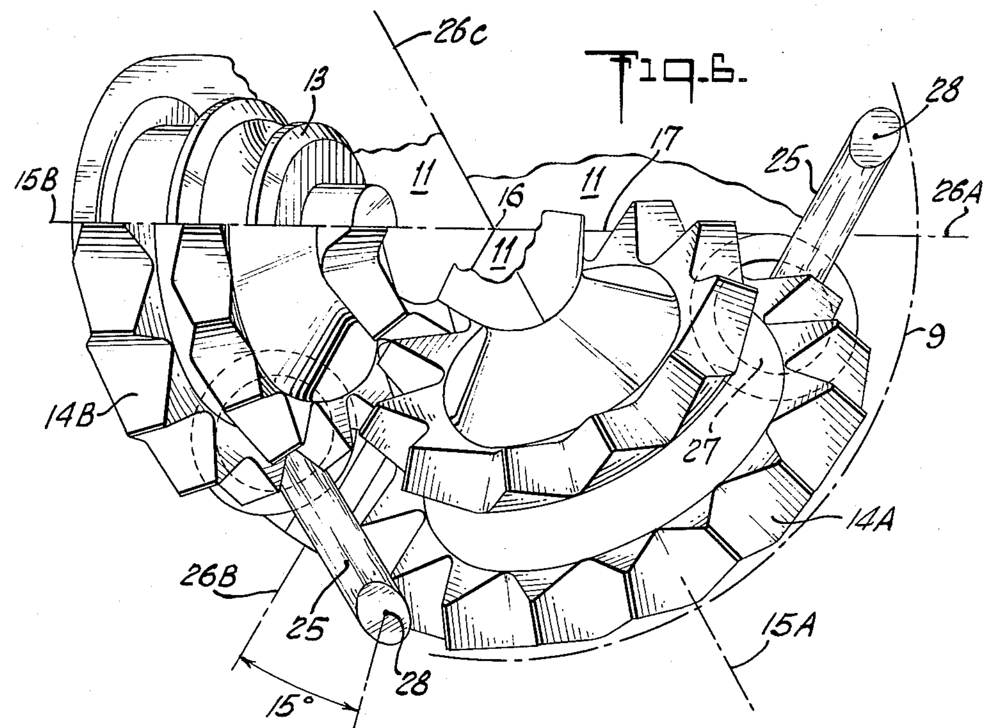
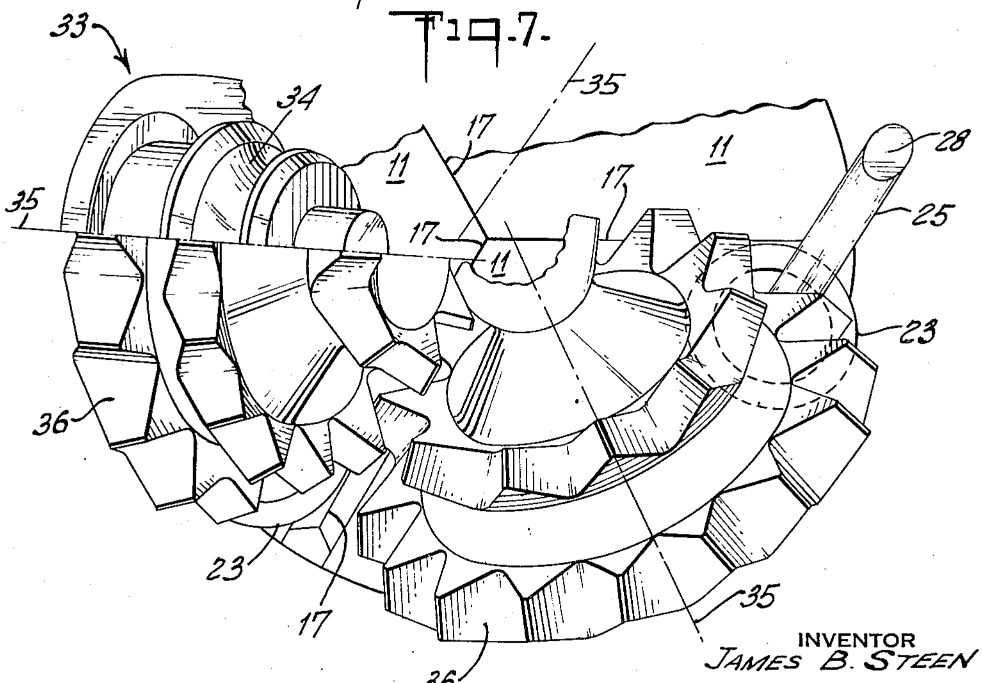


FIG. 7.



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JET ROCK BIT

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9 Claims. (Cl. 175—340)

This invention relates to rotary earth boring drills and particularly to a jet arrangement for discharging a stream of drilling fluid at high velocity on the bottom of the bore hole.

The usual rock bit of the three-cone type comprises a bit head, three legs depending from the head and spaced 120° apart, and three spindles inclined downwardly and inwardly from the legs to support respectively three cone cutters. The cutters occupy a large area over the bottom of the hole and do not allow much space for the discharge of a stream of drilling fluid from a nozzle in the bit head to the bottom of the hole. However, there is a clearance space for the jet streams to pass without interference in each of three localities lying in median planes equi-distant from the spindle axes.

In the usual jet cone bit, there are three jet nozzles each arranged in one of the median planes and mounted in the head with its axis substantially vertical so as to discharge the stream downward along the median plane of clearance between the cutters. The stream impinges on the bottom of the hole at a right angle thereto and disperses the rock particles or chips in different directions. The spot where the stream strikes the bottom of the hole is midway between the cutters, or about 60° in advance of the next cutter. Some of the chips which are dislodged by a leading cutter are washed into the path of the trailing cutter. As a result, the cone cutters roll over a layer of loose chips at the bottom of the hole to re-grind the chips, and the cutter teeth are prevented from penetrating deeply into the earth formation.

An object of the present invention is to improve the penetration of the cone cutters by removing the chips from the path of the approaching cutter. In accordance with this invention, the jet stream is arranged to strike the bottom of the hole at an acute angle instead of at right angles. Preferably, the inclination of the stream is in a leading direction to push the chips toward the cutter which has just dislodged them and away from the cutter which follows, thus confronting each cutter with a clean surface on the bottom of the bore hole.

In addition to the change in the angle of inclination of the jet stream on the bottom of the hole, the present invention departs from the usual practice by changing the spot on the bottom of the hole where the stream strikes, placing it ahead of the median plane of clearance and far ahead of the approaching cutter so that the chips have ample time to escape from the bottom of the hole before the next cutter arrives.

Another object is to direct the stream toward the trailing side of a cutter in approximately a tangential relation thereto, but with the stream and cutter teeth moving in opposite directions with the result that the chips are lifted from the bottom of the hole by the combined effect of the jet fluid turbulence and the churning action of the teeth.

Another object is to reposition the nozzle housing in the bit head so that it will be more effective than previously both during the down flow and during the subsequent up flow of the drilling fluid. By tilting the stream as previously described, it is possible to offset the nozzle and its housing with respect to the median plane of clearance between the cutters without causing interference between the cutters and the stream. This arrangement permits the nozzle housing to be located close to one spindle

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supporting leg and far away from another leg, whereas in the usual jet cone bit the nozzle housing lies midway between the legs or in the median plane of cutter clearance. The offsetting of the nozzle housing permits the entire nozzle housing to be formed integrally in one of the three segments which make up the bit head, without creating the problems which arise when the nozzle housing lies on both sides of the radial plane which separates two segments. It also provides a greater space on the outside of the bit head for the passage of the ascending fluid and entrained chips.

The above objects are attained without sacrificing the advantage of an unimpeded stream. In accordance with this invention, the jet nozzle is located above one of the cutters and spaced from the median plane of clearance between the cutters. However, the inclination of the nozzle is such that the stream may cross the median plane at the level where the cutters are closest to each other and then proceed to a spot on the other side of the median plane.

Other objects and features of the invention will appear more fully from the description which follows.

In the accompanying drawings:

FIG. 1 is an elevational view of a fragmentary portion of a bit head segment forming part of a cone type rock bit according to one form of this invention, and showing the jet nozzle supported in operative position;

FIG. 2 is a bottom plan view of the segment and jet nozzle of FIG. 1, and showing also the nozzle of the following segment;

FIG. 3 is a longitudinal section of a fragmentary part of the rock bit in the plane in the axis of the nozzle;

FIG. 4 is a development view showing portions of two of the cutters in operative relation to the jet stream which passes between them;

FIG. 5 is a diagrammatic view showing one of the jet streams in operative relation to the leading cutter and to the detritus or chips dislodged by the combined cutting and jet action;

FIG. 6 is a bottom plan view of part of the rock bit of FIGS. 1–5 showing one-and-one-half cutters mounted thereon and two of the jet streams issuing from the rock bit; and

FIG. 7 is a view similar to FIG. 6 but showing a modification.

In both forms of invention the jet arrangement is incorporated in a rock bit of the type which comprises a bit head made of three segments arranged respectively to support three cone cutters for rolling over the formation at the bottom of the bore hole 9 (FIG. 6).

Referring to FIGS. 1 and 2, the head segment 10 comprises a body portion 11, a depending leg 12 and a spindle 13, all forming an integral structure such as a steel forging or casting. The spindle supports a cone cutter 14A or 14B (FIG. 6) for rotation about an individual axis 15A or 15B which is inclined downward and inward, and which intersects the vertical axis 16 of the rock bit which latter axis forms the center of the bore hole 9. The segment body portion 11 extends circumferentially for 120° between the two lateral faces 17, each lying in a vertical plane. The lateral faces preferably are in symmetrical relation to the spindle axis 15A that is to say, the plane of the spindle axis bisects the body portion 11, or is spaced 60° from either of the lateral faces 17. The lateral faces are arranged in abutting relation to two other identical segments. The three segments are secured together by the usual means, including holes 18 for receiving dowel pins (not shown) and marginal recesses 19 for receiving welding material (not shown).

The upper part of the body portion 11 is provided at its exterior with the usual screw threads (not shown) for attachment to a drill string by means of which the rock bit may be rotated in a clockwise direction looking downward, or in a counterclockwise direction when viewed as in FIGS. 2 and 6. At its exterior, the upper part of the body portion is provided with a bore sector **20** leading to a cavity **21**. The three bore sectors combine to form a central bore which receives drilling fluid or mud. A passageway **22** extends generally downward from the cavity **21** and opens at the lower end of a hollow boss **23** integral with the segment body **11**. The boss is inclined downward toward the vertical plane of the adjacent lateral face **17** but does not extend beyond it. The passageway **22** is suitably counterbored and grooved to receive a nozzle **24A** or **24B**. The nozzle which is of conventional construction, is shown best in FIG. 3. For a more complete disclosure of the nozzle and its retaining means, reference is made to Payne U.S. Patent 2,855,182. Preferably, the axis of the passageway **22** is directly in line with the axis of the nozzle **24A** to minimize any turbulence that otherwise might be caused by change of direction of the stream of drilling fluid as it approaches the nozzle. The nozzle is arranged to discharge a high velocity stream **25** onto the bottom of the bore hole to wash away and erode the earth formation. The position of the nozzle and the direction of the nozzle axis with respect to the cone cutters **14A**, **14B**, etc., are arranged in a novel manner to produce new results as will be pointed out later.

As seen in FIG. 6, the cones **14A** and **14B**, as well as the third cone, are closely spaced with the circumferential rows of teeth of one cone interfitting within circumferential grooves between the rows of teeth on adjacent cones. At the outer end or heel of each cutter, however, the rows of teeth do not interfit but track each other over the same annular area. In a bit of the cone type, there is very little room for a jet stream to pass between the cutters without obstruction in order to strike the bottom of the hole the full force. The region of maximum clearance between the cone cutters is located between the heel portions of two cutters and in a plane which lies midway between the planes of the spindle axes. As seen in FIGS. 3 and 6, the median planes between the spindle axes **15A** and **15B** are spaced from the latter by 60° in either direction, and are designated **26A** and **26B** respectively. In the prior art, it is common practice to arrange the nozzle with its axis substantially vertical and to direct the jet stream along the planes **26A**, **26B**, and the third median plane. It has been discovered, however, that conventional nozzle arrangements do not result in maximum drilling speed, and that improved results can be obtained by inclining the axis of the nozzle and by changing the position of the spot where the jet stream impinges on the bottom of the bore hole.

For convenience of description, the point where the center of the jet stream leaves the nozzle will be designated **27** and the point where the center of the stream strikes the bottom of the hole will be designated **28**. In the prior art, the nozzle end and the bottom end of the jet stream lie substantially in the same vertical plane as the median plane between the spindle axes. In accordance with this invention, however, the point **27** is shifted rearwardly by about 20° while the point **28** is shifted forwardly by about 15°, making a total displacement of about 35° from one end of the stream **25** to the other. The displacement of the points **27** and **28** is the result of tilting the axis of the nozzle **24A** or **24B** so that the stream is directly forwardly and outwardly as well as downwardly. Both the tilting and the circumferential displacement of the nozzle are necessary in order to attain the results of this invention in a cone bit. If the nozzle is displaced without tilting its axis or if the jet stream is tilted without relocating the nozzle, the jet stream will clash against the cutters. However, in the embodiment of FIGS. 1–6 interference between cutters is prevented or at least minimized because the axis of the jet stream intersects the median plane **26B** at a point **29** which is at the level where the two cutters **14A** and **14B** come closest to each other, as shown in FIG. 4. It should be understood that the circumferential measurements 20° and 15° respectively are by way of example, and not limitation, and it is believed that satisfactory results can be obtained by displacing the nozzle end **27** of the stream **25** by only 10° rearwardly of the median plane of separation between the cutters. The 20° displacement is deemed preferable because it entails a greater inclination of the jet stream.

The effect of the inclined jet stream is shown diagrammatically in FIG. 5. The cutter **14A** operates on the bottom of the hole with a chisel action and removes small particles of earth formation consisting of chips or detritus **31**. These chips are entrained in the drilling fluid or mud which issues from the stream **25** and are carried outwardly at the median plane **26B** and then upwardly along the side of the bit head to the top of the hole **9**. When the drill bit is rotated at high speed, however, the chips have a tendency to remain on or near the bottom of the hole until the succeeding cutter **14B** runs over the chips. In the prior art, the jet stream, which was arranged substantially vertical, had the effect of scattering the chips in different directions, some of them moving rearwardly into the path of the succeeding cutter **14B**. The result was that the cutters continually rolled over a layer of chips which prevented the teeth from penetrating deeply into the solid rock. With the arrangement of this invention, however, the stream **25** is inclined at an acute angle to the bottom of the hole, and the angle of incidence is such that the stream now pushes all of the chips forwardly and away from the next cutter **14B** thus presenting the latter with a clean surface on the bottom of the hole.

Another advantage which is believed to result from the inclination of the stream, and from the relocation of the spot where it strikes the bottom of the earth, resides in the turbulence imparted to the stream after it strikes the bottom of the hole and starts moving outwardly and upwardly. As shown in FIG. 4, the stream **25** comes very close to the leading cutter **14A**. In FIG. 5, the distance between the stream and the cutter is exaggerated in order to show the action more clearly. It will be understood, however, that the cutter **14A** and particularly the teeth in the heel row, due to the close proximity of said teeth with the stream, have an effect of changing the course of the stream after it strikes the ground. With this arrangement, the rebounding stream is directed toward the cutter **14A** and is then churned upward by the cutter teeth which act in the manner of a paddle wheel. The upwardly moving stream entrains the chips **31**. The churning action contributes to the quick removal of the chips **31** because the latter have a higher specific gravity than the fluid in the jet stream and therefore would tend to remain on the bottom of the hole if the stream were not properly directed.

The invention reduces the resistance to the outward passage of the chip-laden fluid from the bottom to the side wall of the hole. Referring to FIGS. 4 and 6, the position of maximum clearance between the adjacent cutters and therefore of minimum resistance to egress of chips lies in the median plane **26B**; and the spot **28** of impingement of the stream **25** is displaced by about 15° in advance of the clearance plane. This displacement permits the flow of a substantial quantity of chips **31** following impingement and during conditions of minimum obstruction as the rock bit advances relatively to the chips and carries the plane of the clearance space over the area of the loosened chips.

The invention increases the interval of time between the instant of impingement of a chip by the jet stream, and the instant that the succeeding cutter arrives at the spot of impingement and this interval is adequate to permit the chips which are dislodged by one cutter to pass out of the bottom of the hole before the next cutter arrives. The increased time interval is due in part to the fact that the spot of impingement 28 lies far ahead of the cutter which follows. With the arrangement shown, the rock bit must revolve 75° before the cone cutter 14B can reach the spot where the chip was at the instant of impingement, but if the loosened chip has not been carried from the bottom of the hole by that time, it will not be overtaken by the cutter until the rock bit has turned an additional amount corresponding to the distance of circumferential displacement of the chip during its upward movement subsequent to impingement. This additional circumferential distance, which is a distinctive characteristic of this invention, results from the fact that the stream is inclined forwardly and continues swirling ahead of the approaching cutter and along with the entrained chips after the fluid has reached bottom. The stream 25, unlike the stream in the usual jet cone bits, starts its jetting action at a circumferential speed considerably in excess of the speed of rotation of the bit head, and if the stream has a very high velocity it may swirl along the bottom of the hole to increase its lead on the following cutter 14B before its slows down to permit the cutter to overtake the stream. In the same manner, the drilling fluid may carry the entrained chip for a longer period of time than for 15° of bit rotation, during the period when egress is very rapid and before the chip has been overtaken by the median plane of clearance 26B. In the usual jet cone bit of the prior art, however, the interval of time between the instant of impingement of a chip by the jet stream and the instant that the succeeding cutter rolls over the chip, is limited to correspond to about 60° of revolution of the rock bit; and during that entire interval the egress is at a relatively slow rate because the chips have been passed by the median plane of maximum cutter clearance.

If the jet stream is discharged at a low velocity in relation to the speed of rotation of the rock bit, the spot of impingement 28 may be somewhat less than 15° ahead of the median plane 26B, or 75° ahead of the position 25B of the next cutter, due to the fact that the entire rock bit advances during the interval between the time that the stream leaves the nozzle opening 27 and the time when it strikes the bottom of the hole. However, the reduction in circumferential spacing due to drill bit rotation is not significant because the stream in the practice of this invention is delivered at a very high velocity, and for the further reason that the revolving nozzle imparts to the jet stream a motion of translation which is superimposed on the motion along the axis of the nozzle with the result that the stream tends to follow a helical course and substantially maintain its lead over the following cutter.

The offsetting of the nozzle 24A or 24B from the median plane of cutter clearance results in another advantage because it makes possible a relocation of the spindle axis with respect to the end faces 17 of the head segments 10. In the prior art, it was the usual practice to space the nozzles and spindles 60° apart. That arrangement necessitated the choice between a design in which the nozzle housing on one segment extended beyond the plane of abutment with an adjacent segment, or on the other hand, a design in which the head segment which is otherwise symmetrical has a lopsided spindle on which the entire weight of the rock bit and thousands of feet of superstructure are supported. Either one of these designs created engineering problems which have been obviated by the nozzle of the present invention. Referring to FIG. 2, the nozzle housing 23 is spaced rather closely to the leg 12 on the same segment and therefore is spaced widely from the leg on the adjacent segment. The wide spacing provides a recess on the side wall of the bit head, above the spot 28, which permits free upward movement of the drilling fluid and entrained chips after they have passed from the bottom of the hole.

FIG. 7 shows the invention as applied to a modified type of rock bit in which the spindles are shifted so that the axis of rotation of each cone is askew with relation to the axis of revolution of the rock bit. Apart from the specific jet arrangement, the skew type of cone bit is well known in the art and is described more fully in Garfield U.S. Patent 2,148,372, February 21, 1939. The modified rock bit 33 comprises three head segments each having a body portion 11, a depending leg (not shown) and a hollow boss 23 providing a housing for a nozzle (not shown), all arranged as in FIGS. 1 and 3.

The modified spindles 34, however, are not arranged as the spindles 13 but instead are mounted on axes 35 which do not intersect each other or the axis of revolution of the bit. Each spindle supports a cutter 36 having a tooth formation similar to that of the corresponding cutter 14A, 14B, etc., in FIG. 6. As in FIG. 6, the heel portion of the cutter 36 lies approximately midway between the ends of the lateral faces 17 on the body 11. The apex portions of the cutters 36, however, are shifted so that they lie closer to the leading face 17 of the segment than to the trailing face. The region of maximum clearance between the cutters lies in a plane midway between the planes of the lateral faces 17, as in the first form of invention. The jet stream 25 is discharged in the same direction and strikes the bottom of the hole in the same spot 28 as in the case of FIG. 6 but there is a slightly modified action of the drilling fluid after it reaches the bottom of the hole.

In the first form of invention, the teeth on cutter 14A churn the stream 25 and chips 31 upwardly as previously described and as shown in FIG. 5. In the modification of FIG. 7, however, the teeth on cutters 36, due to the skew of the cone, appear to have the property of churning the stream and chips in a direction which is outward as well as upward.

While the invention has been described with reference to a drilling fluid of the liquid type, such as mud or slush, it is also adapted for the use of other kinds of drilling fluid such as air or gas.

What is claimed is:

1. A jet cone bit comprising a plurality of head segments; each comprising a body portion, a nozzle housing and a depending leg all integrally formed together, each head segment having lateral faces disposed in intersecting vertical planes 120° apart, the segments abutting each other at said lateral faces, said nozzle housing being disposed adjacent one of the lateral faces and entirely on one side of the vertical plane thereof, a spindle associated with each depending leg and projecting downwardly and inwardly therefrom, each spindle being disposed approximately midway between the planes of said lateral faces; a cone cutter on each of said spindles; and a nozzle mounted in said nozzle housing and enclosed thereby around its entire circumference, each nozzle having an outlet which lies directly above the associated cutter, said nozzle having an axis inclined circumferentially to direct a stream of drilling fluid in a combined circumferential and downward direction with the stream passing between the cutters at a point which is offset circumferentially from the nozzle outlet, and finally striking the bottom of the hole at a point closer to the cutter on an adjacent segment than to the cutter carried by the associated segment which supports the nozzle.

2. A jet cone bit according to claim 1, in which the nozzle is disposed near the leading face of the head segment, and is inclined to direct the stream in a downward and forward direction across the plane of the leading face to move the detritus at the bottom of the hole forwardly and away from the cone cutter below the nozzle.

3. In a jet cone bit, a head segment formed in one piece and comprising a body portion, a nozzle housing and a depending leg, said head segment having lateral faces disposed in intersecting vertical planes 120° apart, said head segment being disposed entirely within the region limited

by said vertical planes, a spindle carried by the depending leg and projecting downwardly and inwardly therefrom the spindle being disposed substantially midway between the planes of said lateral faces; a cone cutter rotatable on said spindle, and a nozzle mounted in said nozzle housing, said nozzle being located above said cutter with its outlet in direct vertical alinement with a portion of the cutter surface whereby said cutter precludes the issuance of a vertical jet stream from the nozzle to the bottom of the hole, said nozzle having an axis inclined circumferentially to direct a stream of drilling fluid in a slanted direction to by-pass the cutter and strike directly against the bottom of the bore hole.

4. A jet cone bit comprising a bit head having three depending legs, a spindle supported by each of said legs and extending downwardly and inwardly, the axes of the spindles lying in vertical planes 120° apart and intersecting each other at the axis of revolution of the bit, cone cutters mounted on said spindles to cut the entire formation at the bottom of the hole, said cutters providing clearance therebetween at three median vertical planes spaced 60° from the spindle axes, and one or more nozzles carrid by the bit head, each nozzle being positioned above the forward portion of an associated cutter with its outlet offset rearwardly from the median plane by at least 10°, the axis of the nozzle being inclined circumferentially forward to direct the stream of drilling fluid across the median plane and through the clearance space between the associated cutter and the leading cutter to strike the bottom of the hole at a point closer to the leading cutter than to the associated cutter, the stream being slanted to syeep the chips forwardly along the bottom of the hole out of the path of the associated cutter.

5. A jet cone bit according to claim 4, in which the vone cutters have rows of teeth in interfitting relation, the interfitting teeth being located inwardly of the heel row of teeth, the latter being arranged to track each other over a marginal area at the bottom of the hole, the axis of the nozzle being inclined radially outward as well as circumferentially forward to direct the stream of drilling fluid to the marginal area.

6. A jet cone bit according to claim 5, in which the nozzle axis is so inclined that the stream lies in a vertical plane substantially parallel to that of the vertical axis of the leading spindle, the angle of incidence of the stream on the bottom of the hole being such as to blast the chips in a forward and outward direction along the bottom of the hole.

7. A jet cone bit comprising a bit head having three depending legs, a spindle supported by each of said legs and extending downwardly and inwardly, the axes of the spindles being askew with relation to the vertical bit axis at the center of the hole, cone cutters mounted on said spindles to cut the entire formation at the bottom of the hole, said cutters providing clearance therebetween at three regions approximately midway between the spindle axes, and one or more nozzles carried by the bit head, each nozzle being positioned above one of the cutters and offset rearward from the nearest clearance region, the axis of the nozzle being inclined circumferentially forward to direct the stream of drilling fluid through the clearance space between two adjacent cutters to strike the bottom of the hole directly without interference by the cutters the angle of incidence of the stream on the bottom of the hole being such as to blast the chips forwardly and outwardly along the bottom of the hole and thereby sweep then out of the path of the following cutter.

8. In a jet cone bit, a head segment formed in one piece and comprising a body portion, a hollow boss and a depending leg, said head segment having lateral faces disposed in vertical planes radiating from the axis of rotation of the bit, a spindle connected to the depending leg and extending downwardly and inwardly therefrom, said spindle being disposed substantially midway between the vertical planes of said lateral faces; a cone cutter rotatable on said spindle, said hollow boss being located at the leading side of the segment adjacent the leading lateral face, the lower portion of the boss providing a nozzle housing, a nozzle mounted in said nozzle housing, said nozzle being located entirely in a position rearward of the vertical plane of the leading lateral face, said nozzle mounted with its axis slanted in a circumferentially forward direction to discharge a stream of drilling fluid across the vertical plane of the leading lateral face, said stream being directed to strike the bottom of the bore hole at a point forward of the leading lateral face.

9. In a jet cone bit, a head segment according to claim 8 which includes an inlet passage above the nozzle for delivering drilling fluid thereto, said inlet passage being axially alined with the nozzle to minimize turbulence.

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