Dec. 31, 1968 G. H. F. GARDNER 3,419,091

METHOD AND APPARATUS FOR DRILLING WELLS WITH ECCENTRIC JET DRILLS

Filed March 30, 1967

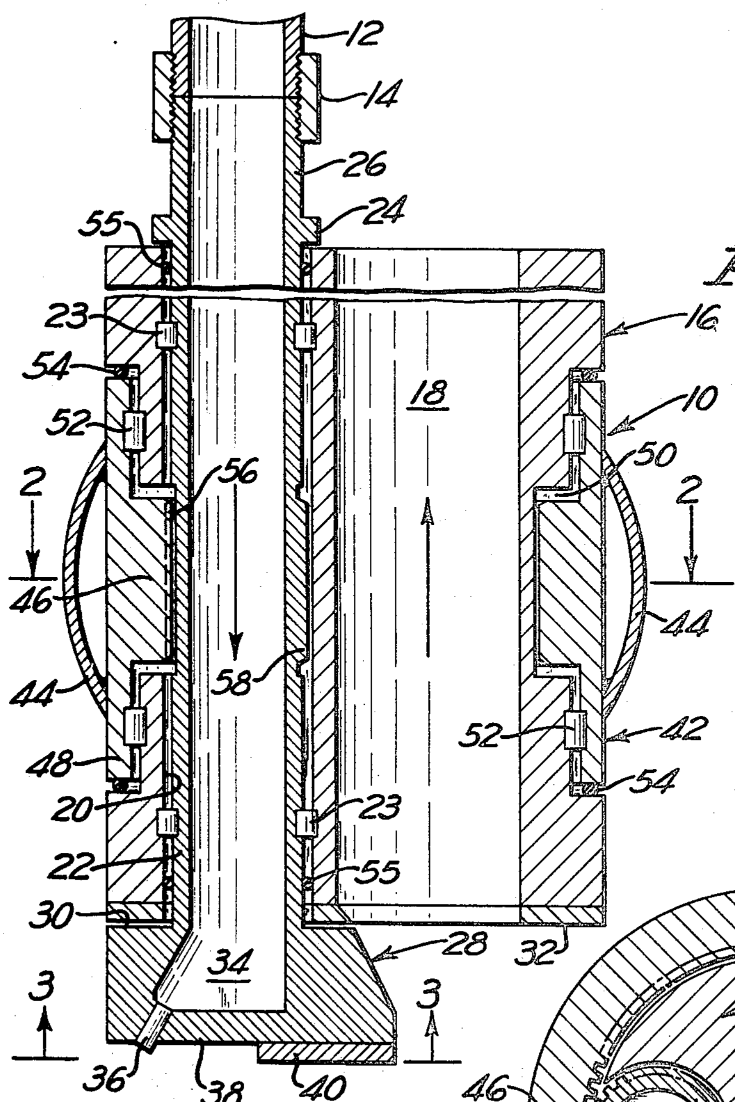

Fig.1

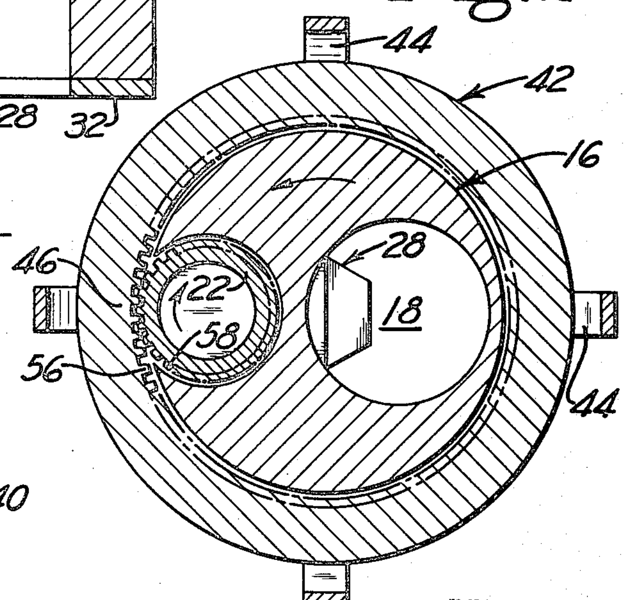

Fig.2

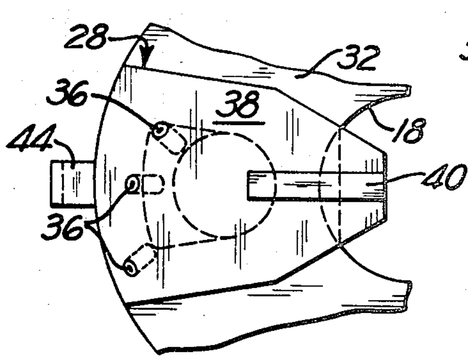

Fig.3

INVENTOR.
GERALD H. F. GARDNER

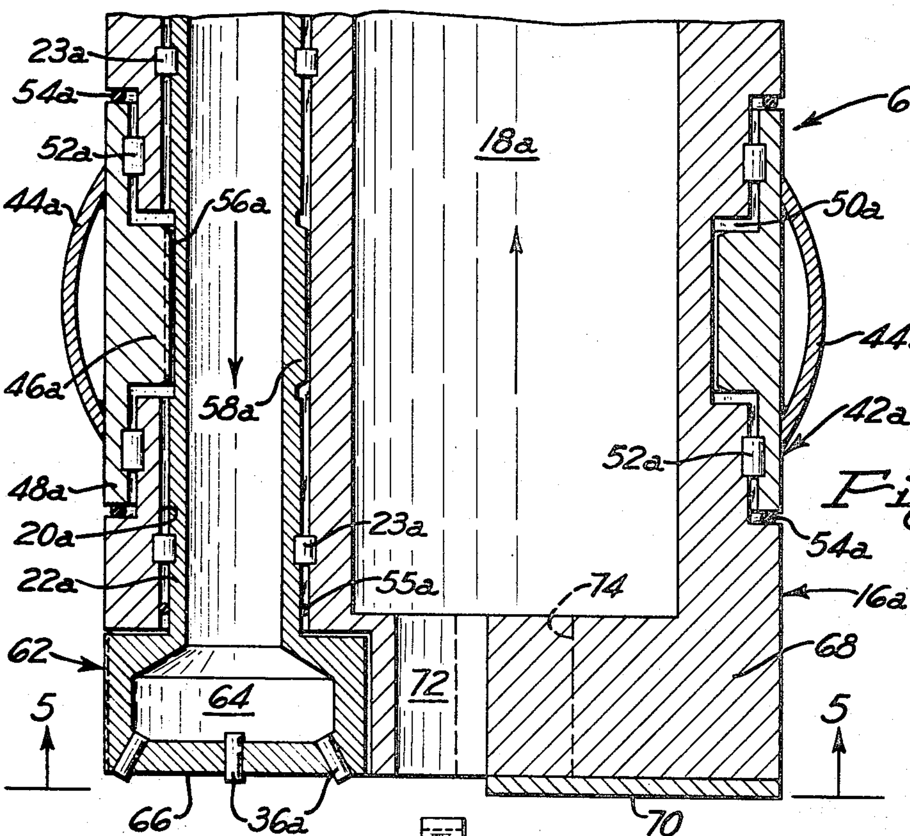

Fig. 4

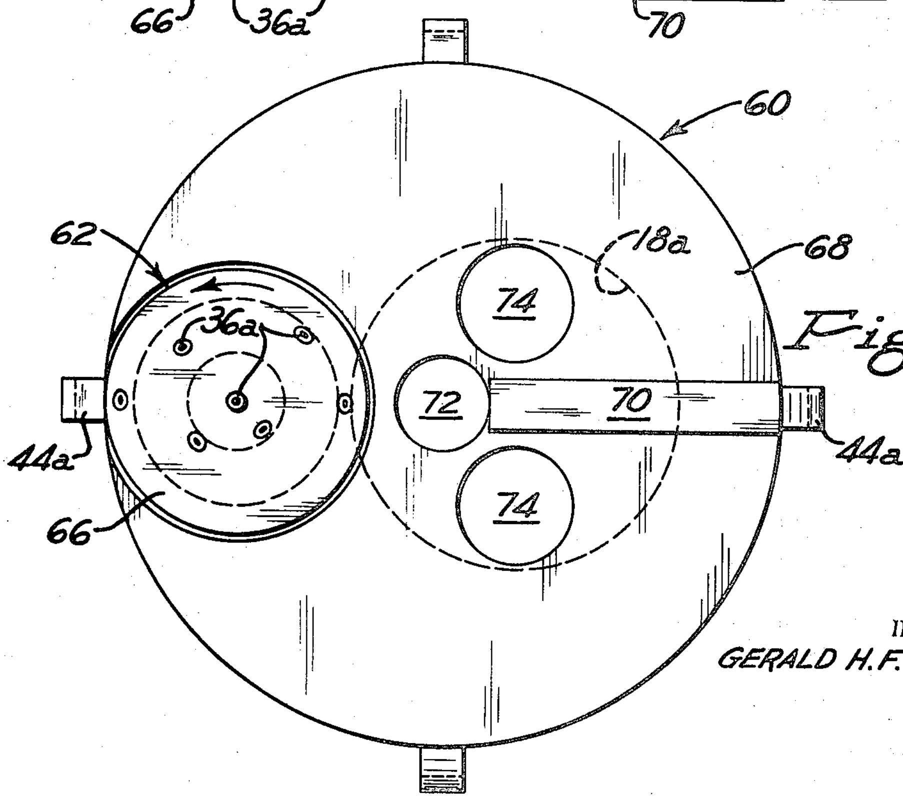

Fig. 5

INVENTOR.
GERALD H. F. GARDNER

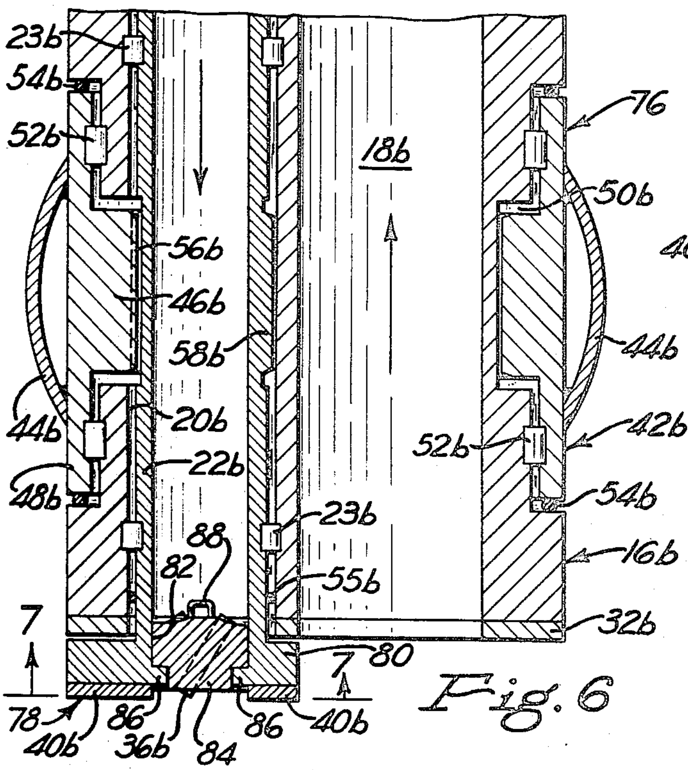

Fig. 6

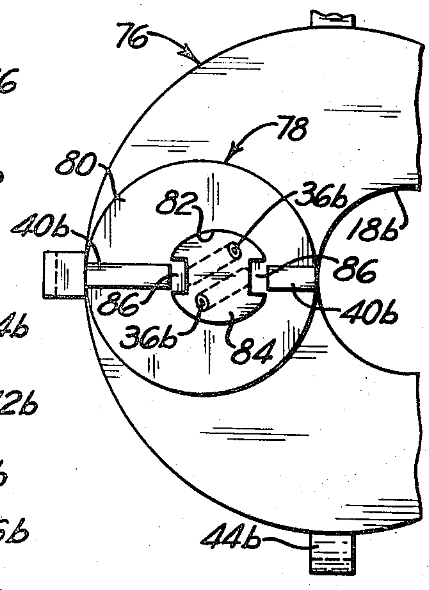

Fig. 7

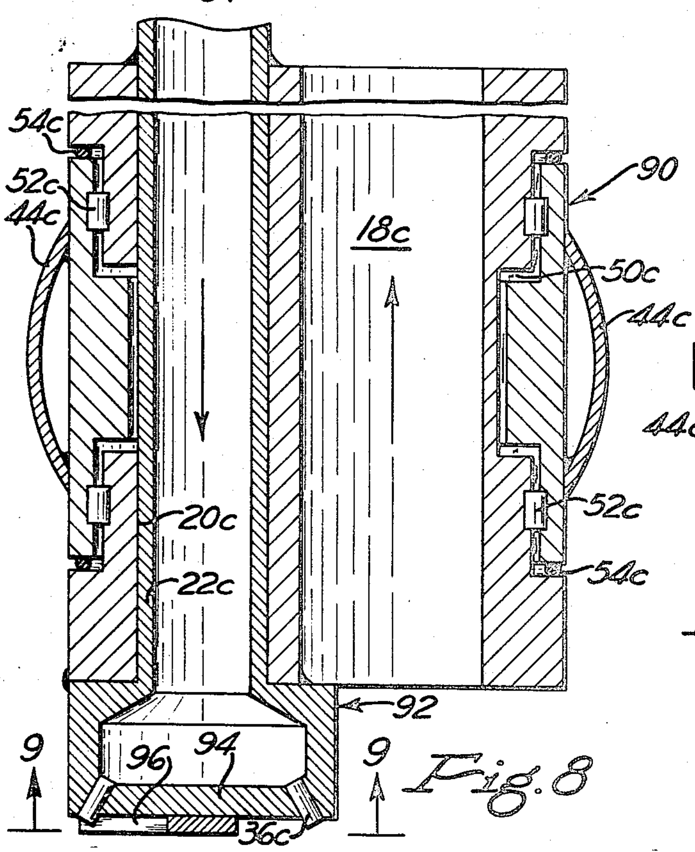

Fig. 8

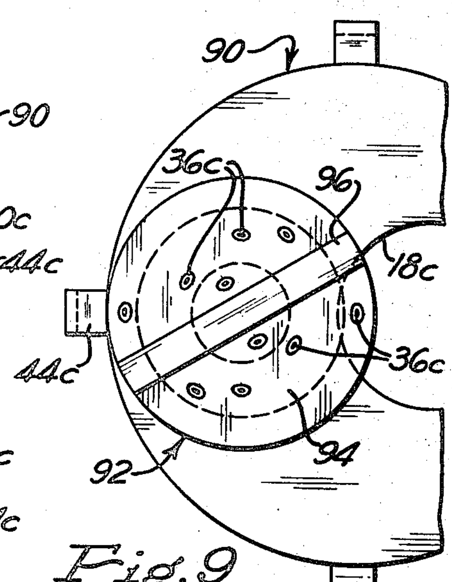

Fig. 9

INVENTOR.
GERALD H. F. GARDNER

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METHOD AND APPARATUS FOR DRILLING WELLS WITH ECCENTRIC JET DRILLS

Gerald H. F. Gardner, Pittsburgh, Pa., assignor to Gulf Research & Development Company, Pittsburgh, Pa., a corporation of Delaware

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ABSTRACT OF THE DISCLOSURE

Method and apparatus for drilling earth boreholes by means of high pressure jets of an abrasive-laden slurry wherein the drill head is substantially smaller than the diameter of the hole, is mounted off-center with respect to the axis of the hole, and is caused to rotate eccentrically within the hole.

This invention pertains to drilling wells in the earth by means of high velocity jets of an abrasive-laden slurry and an eccentric drill. The invention comprises drill heads which are considerably smaller than the diameter of the hole being drilled. The drill head, and the drill pipe carrying the drill head, is mounted in the drill off-center or eccentrically with respect to the axis of the hole, and means are provided to cause the nozzle or nozzles to traverse the entire bottom of the hole. By using a drill head considerably smaller than the diameter of the hole, as opposed to a drill bit in which the cross-sectional area is substantially equal to or at least of the same orders of magnitude as the borehole, fewer but larger nozzles can be used. The use of larger nozzles permits the use of larger abrasive particles in the drilling slurry which it is anticipated will result in increased drilling rate.

The use of a smaller number of larger nozzles permits a higher jet velocity using a smaller volumetric flow through the drill pipe. That is, for any given power input at the surface, a smaller number of larger nozzles will produce a higher jet velocity and a lower volumetric flow rate through the drill pipe than would a larger number of smaller nozzles. The greater volume of formation removed by the higher jet velocity more than compensates for the smaller number of nozzles. Lessening the volumetric flow rate through the drill pipe lowers the friction loss in the drill pipe, and hence increases the efficiency of transfer of power from the surface pumps to the nozzles. This benefit increases with depth because of the increased length of drill pipe.

If carried to its logical end, a drill with only one nozzle would be provided. A problem in drilling a relatively large hole with one nozzle is the provision of a substantially uniform removal rate all over the bottom of the hole. In those embodiments of the present invention in which the nozzles are moved eccentrically over the bottom of the borehole, a single nozzle as well as a plurality of nozzles may be provided. Hence, the present invention encompasses an eccentric drill having only one nozzle.

In the accompanying drawing forming a part of this disclosure, FIG. 1 is a vertical, sectional view of a first embodiment of a drill embodying the invention; FIG. 2 is a cross-sectional view taken on line 2—2 of FIG. 1; FIG. 3 is a partial bottom plan view of a portion of the drill of FIG. 1 taken on line 3—3 thereof; FIG. 4 is a view similar to FIG. 1 showing a second embodiment; FIG. 5 is a bottom plan view taken along line 5—5 of FIG. 4; FIG. 6 is a view similar to FIG. 1 showing a third embodiment; FIG. 7 is a partial bottom plan view taken along line 7—7 of FIG. 6; FIG. 8 is a view similar to FIG. 1 of a fourth embodiment; and FIG. 9 is a bottom plan view taken along line 9—9 of FIG. 8.

Referring now in detail to the drawing, a first embodiment of the apparatus of the invention is shown in FIGS. 1 through 3, and comprises a drill **10**. Drill **10** is removably mounted on the lower end of a drill string **12** by any conventional connector means **14**, and comprises a main drill body **16**. Drill body **16** is formed with an off-center longitudinal through opening **18** to permit the return flow of the drilling fluid, abrasives, and cuttings back to the surface. Body **16** is formed with a second longitudinal through opening **20**, in which is mounted a drill stem member **22** by means of bearing **23**. The upper end of drill stem **22** is formed with an upper stop flange **24** which has an outside diameter larger than the diameter of opening **20** to prevent downward movement of stem **22** with respect to body **16**. The upper extension **26** of drill stem **22** is joined to drill string **12** by means of connector **14**. The lower end of drill stem **22** is formed into a drill head **28**. It will be apparent that drill head **28** could be also formed as a separate member and joined to the drill stem by conventional means.

Drill head **28** comprises an upper surface **30** which is in closely spaced relation to the undersurface of a bottom plate **32** on the undersurface of body **16**. Thus, surface **30** and flange **24** prevent any substantial relative motion between body **16** and drill stem **22**, and hold body **16** and stem **22** together. Drill head **28** comprises an internal slurry receiving chamber **34**. At least one nozzle **36** extends through the bottom portion **38** of drill head **28** and is in fluid communication with chamber **34**. As shown in FIG. 3, drill head **28** carries three nozzles, but a single nozzle could be provided if desired. Drill head **28** is also provided with a stand-off bar **40** of hard abrasion resistant material such as tungsten carbide which rides against the bottom surface of the borehole to maintain the stand-off of the exit end of the nozzle or nozzles from the borehole bottom, and also serves to physically break off any minor ridges which may remain between the grooves cut by the abrasive slurry.

Means are provided to transform the rotation of the drill string **12** about its own axis imparted to it by the conventional rotary drilling equipment at the surface (not shown) into simultaneous rotation of drill head **28** about both the axis of drill stem **22** and the axis of drill **10**. The axis of drill **10** will substantially coincide with the axis of the hole being drilled. To this end, a fixed housing **42** is provided, and comprises a plurality of bow type centralizer springs **44** which cooperate with the side wall of the borehole to hold housing **42** stationary as to rotation in the borehole with respect to its own axis. The springs **44** will permit the drill **10** to move axially in the borehole, as is well known. Housing **42** comprises a housing body comprising a thickened central portion **46** and a pair of flange portions **48** extending outwardly from the outside of thickened central portion **46**. The body of housing **42** fits within a suitably formed opening **50** formed in body **16**. Suitable bearings **52** are provided to permit rotation of drill body **16** with respect to fixed housing **42**, and sealing means **54**, such as O-rings or the like, are provided to prevent the flow of any well fluids into the joints and bearings.

The body of housing **42** is a ring-like member and encircles the drill **10** within its opening **50**, so that drill **10** has a smooth outer surface, except for springs **44**. The inside cylindrical surface of central portion **46** is formed with gear teeth **56**. As is shown in FIG. 2, drill stem **22** is positioned within body **16** so that it is close to the plane of the surface carrying gear teeth **56**. A portion of drill stem **22** is formed with gear teeth **58** which mate with gear teeth **56**.

The upper end of drill **10** is shown broken in FIG. 1. The length of the drill will be determined by the weight required for efficient drilling, and it will be understood that if needed, another member like housing **42** may be provided for added stability and to insure smooth operation.

The kinetic relationship between drill stem **22** and thickened portion **46** is that of a planetary/sun gear arrangement, with thickened portion **46** comprising the fixed "sun" gear. As is well known, by suitable selection of the number of gear teeth **56** and **58**, a relationship can be created that will insure that the nozzle or nozzles **36** will be in a different position each time they come to any one reference position with respect to housing **42**. Thus, each nozzle will describe a path on the borehole bottom which will have the geometric configuration of a generalized hypocycloid.

Referring now to FIGS. 4 and 5, there is shown a second embodiment **60** of the apparatus of the invention. Drill **60** is adapted to cut cores as it drills. Parts similar to those described above in regard to drill **10**, are indicated by the same reference numerals followed by an "*a*."

The lower end of drill **60** differs from the lower end of drill **10**. A drill head **62** is provided in place of drill head **28** and comprises a slurry receiving chamber **64**. The bottom wall portion **66** of drill head **62** is provided with a plurality of nozzles **36*a***. Drill **60** comprises a thickened bottom closure plate portion **68**. As shown in FIG. 5, bottom plate portion **68** carries a stand-off bar **70** positioned opposite drill head **62**. Bottom plate portion **68** is formed with a core chamber **72** which is cylindrical and coaxial with the axis of the drill. A pair of fluid return passages **74** are formed in bottom plate **68** to communicate the space below the drill with fluid return hole **18*a***.

As drill **60** is operated, a cylinder of material will be continuously formed in core chamber **72** and will periodically break off due to vibrations of the drill. The cores will be carried up to the surface with the return flow in passage **18*a***.

Referring now to FIGS. 6 and 7, there is shown a third embodiment **76** of the apparatus of the invention. Drill **76** incorporates the feature of a retrievable nozzle. That is, with drill **76** it is possible to remove and replace only the nozzles without pulling the drill and drill string out of the borehole. Parts similar to those described above in regard to drill **10**, are indicated by the same reference numerals followed by a "*b*."

The lower end of drill **76** is provided with a drill head **78**, which comprises a bottom plate portion **80** formed with a nonround opening **82** in which is seated a drill holder **84** having an external configuration to fit snugly within opening **82**. Bottom plate **80** is also formed with a pair of inwardly extending lugs **86** that fit within suitably formed slots in the side of holder **84**, to prevent holder **84** from falling out downwardly of the drill head **78**. The upper surface of holder **84** is provided with a device **88**, such as a handle or latch, which is adapted to cooperate with a suitable "fishing tool." Thus, a "wire line" can be dropped down the inside of the drill string and drill stem **22*b*** to grasp holder **84** by latch or handle **88** to pull the holder and its nozzles **32*b*** out of the hole for replacement of the nozzles on the surface. The nonround shape and the lugs **86** assure proper seating of the holder in drill head **78** and also prevent any relative rotational motion in a horizontal plane between the drill head and the nozzle holder.

Referring now to FIGS. 8 and 9, there is shown a fourth embodiment **90** of the apparatus of the invention. Drill **90** is a modification of the apparatus of the invention wherein the rotation of the drill string around its own axis imparted to it by the rotary equipment at the surface is wholly transformed into rotation of the drill stem about the axis of the drill. Parts similar to those described above in regard to drill **10** are indicated by the same reference numerals followed by a "*c*."

In drill **90**, flange **24** is omitted and drill stem **22*c*** is fixed with relation to opening **20*c*** by any suitable means such as welding. Nothing equivalent to gear teeth **56** and **58** of drill **10** are used in drill **90**.

A drill head **92** is provided and comprises a bottom plate portion **94** provided with a stand-off bar **96** and a plurality of nozzles **36*c***. As shown in FIG. 9, the diameter of drill head **92** is at least equal to and preferably slightly larger than the radius of drill **90**. Since the drill head **92** does not rotate about the axis of drill stem **22*c***, the pattern cut in the bottom of the borehole by the nozzles **36*c*** will comprise a plurality of concentric circles. Therefore, the nozzles **36*c*** are positioned in bottom plate **94** at appropriate radii and appropriate angles to leave a minimum amount of the formation between them to be broken off by stand-off bar **96**.

As will be clear to one skilled in this art, the four drill heads described, **28**, **62**, **78** and **92** are substantially interchangeable as shown, and fully interchangeable with only minor changes. For example, drill head **78** could be used in place of drill head **28** or **62** with only an adjustment of dimensions to assure that the retrievable holder **84** reaches out to the outside of the borehole.

While the invention has been described in detail above, it is to be understood that this detailed description is by way of example only, and the protection granted is to be limited only within the spirit of the invetnion and the scope of the following claims.

I claim:

1. A method of drilling earth boreholes by the use of a high velocity jet of an abrasive-laden slurry, rotary surface drilling equipment, and a drill string; comprising the steps of mounting a slurry jetting means in a drilling head having the diameter equal to about half the diameter of the hole being drilled, and transforming the rotation of the drill string about its own axis imparted to it by the surface rotary drilling equipment into rotation of said drill head about the axis of the borehole.

2. The method of claim **1**, and transforming the rotation of the drill string about its own axis imparted to it by the surface rotary drilling equipment into simultaneous rotation of said drill head about the axis of the drill string and the axis of the borehole.

3. A method of drilling earth boreholes by the use of a high velocity jet of an abrasive-laden slurry, comprising the steps of mounting a slurry jetting means eccentrically with respect to the axis of the hole being drilled, rotating said jetting means about a first axis, positioning said first axis off-center with respect to the axis of the borehole, and rotating said first axis about the axis of the borehole simultaneously with the rotation of said jetting means about said first axis.

4. Apparatus for drilling earth boreholes by means of a high velocity jet of an abrasive-laden slurry comprising a drill string, a drill at the lower end of said drill string, means at the surface to impart rotary motion to said drill string about its own axis, said drill comprising a drill stem, means to connect the upper end of said drill stem to the lower end of said drill string, a drill head at the lower end of said drill stem, said drill head having a largest dimension parallel to the plane of the bottom of the borehole equal to about half the diameter of the borehole being drilled, said drill head comprising a nozzle communicating the inside of said drill stem with the space below said drill, said drill being formed with a longitudinal return opening extending through the lentgh thereof and communicating the space below said drill with the space above said drill, the axis of said drill stem being parallel and offset from the axis of said drill, said drill comprising a portion adapted to be fixed to the wall of the borehole against rotation about the axis of the drill and to permit motion of said drill along the axis of said drill, and means to permit rotation of said drill stem on said fixed portion about the axis of said drill.

5. The combination of claim **4**, said rotation permitting means further comprising means cooperative with a portion of said drill stem to cause said drill stem to rotate about its own axis simultaneously with its rotation about the axis of the drill.

6. The combination of claim **5**, said cooperating means comprising gear teeth formed on a portion of the outside of said drill stem and mating gear teeth formed on the inside surface of said fixed portion.

7. The combination of claim **4**, said drill head comprising a nozzle holder removably seated therein, said nozzle being mounted in said nozzle holder, and said nozzle holder comprising means to permit the removal of said nozzle holder by the use of a wire line passing through the inside of said drill string and said drill stem, whereby said nozzle may be retrieved or replaced without removing said drill string and said drill from the borehole.

8. The combination of claim **5**, said drill head comprising a nozzle holder removably seated therein, said nozzle being mounted in said nozzle holder, and said nozzle holder comprising means to permit the removal of said nozzle holder by the use of a wire line passing through the inside of said drill string and said drill stem, whereby said nozzle may be retrieved or replaced without removing said drill string and said drill from the borehole.

9. The combination of claim **8**, said nozzle holder comprising a nonround, transverse cross-sectional shape, said drill head being formed with an opening having a cross-sectional shape adapted to make with the shape of said nozzle holder, and said nozzle holder and drill head comprising means to prevent said nozzle holder from moving downwardly with respect to said drill.

10. The combination of claim **4**, said drill comprising a bottom plate member coplanar with said drill head, whereby said bottom member and said drill head substantially close off the bottom end of said drill; said bottom member being formed with an axial cylindrical opening coaxial with the axis of the drill, said axial cylindrical opening communicating the space below said drill with said longitudinal return opening, whereby said drill will cut a core of the formation being drilled.

11. The combination of claim **5**, said drill comprising a bottom plate member coplanar with said drill head, whereby said bottom member and said drill head substantially close off the bottom end of said drill; said bottom member being formed with an axial cylindrical opening coaxial with the axis of the drill, said axial cylindrical opening communicating the space below said drill with said longitudinal return opening, whereby said drill will cut a core of the formation being drilled.

12. The combination of claim **10**, said bottom plate member being provided with a stand-off bar of hard abrasion resistant material extending down below the lowermost surface of said bottom plate member and said drill head, and said stand-off bar being positioned on the

opposite side of said axial cylindrical opening from said drill head.

13. The combination of claim **4**, said drill comprising an elongated cylindrical drill body, said portion fixed against rotation about the axis of the drill comprising a fixed housing, said fixed housing having an outer cylindrical surface substantially coplanar with the outer cylindrical surface of said body, rotary fluid sealing means between said fixed housing and said drill body, sealing means between said fixed housing and said drill body, and said fixed housing comprising a plurality of bow springs extending outwardly from the outer cylindrical surface of said fixed housing and adapted to engage the side wall of the borehole.

14. The combination of claim **4**, said drill head comprising a stand-off bar of hard abrasion resistant material extending down below the lowermost surface of said drill head.

15. The combination of claim **4**, the bottom surface of said drill being provided with a bottom plate member of hard abrasion resistant material, the upper surface of said drill head being positioned in closely spaced relation to the bottom surface of said bottom plate member.

16. The combination of claim **4**, said drill stem comprising flange means extending outwardly from the outer surface thereof in closely spaced relation to the upper surface of said drill, whereby said drill is constrained against upward axial motion along said drill stem.

17. The combination of claim **5**, said drill head comprising a single nozzle, and said rotation permitting means and said cooperating means being adapted to cause the jet from said single nozzle to cover substantially the entire bottom surface of the borehole.

18. The combination of claim **17**, said drill head comprising a stand-off bar of hard abrasion resistant material extending down below the lowermost surface of said drill head.

19. The combination of claim **4**, said drill head comprising a plurality of said nozzles, and said drill head comprising a stand-off bar of hard abrasion resistant material extending down below the lowermost surface of said drill head.

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NILE C. BYERS, Jr., *Primary Examiner.*

U.S. Cl. X.R.

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