United States Patent [19]
Juvkam-Wold

[11] 3,838,742
[45] Oct. 1, 1974

[54] DRILL BIT FOR ABRASIVE JET DRILLING

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[22] Filed: **Aug. 20, 1973**

[21] Appl. No.: **389,569**

[52] U.S. Cl. **175/380**, 175/67, 175/393, 175/422
[51] Int. Cl. **E21b 7/18**
[58] Field of Search 175/380, 67, 422, 327, 175/335, 331, 336, 15, 393

[56] **References Cited**

UNITED STATES PATENTS

3,384,192	5/1968	Goodwin et al.	175/67 X
3,414,070	12/1968	Pekarek	175/393
3,542,142	11/1970	Hasiba et al.	175/422 X
3,583,503	6/1971	Coski et al.	175/336 X
3,688,852	9/1972	Gaylord et al.	175/393

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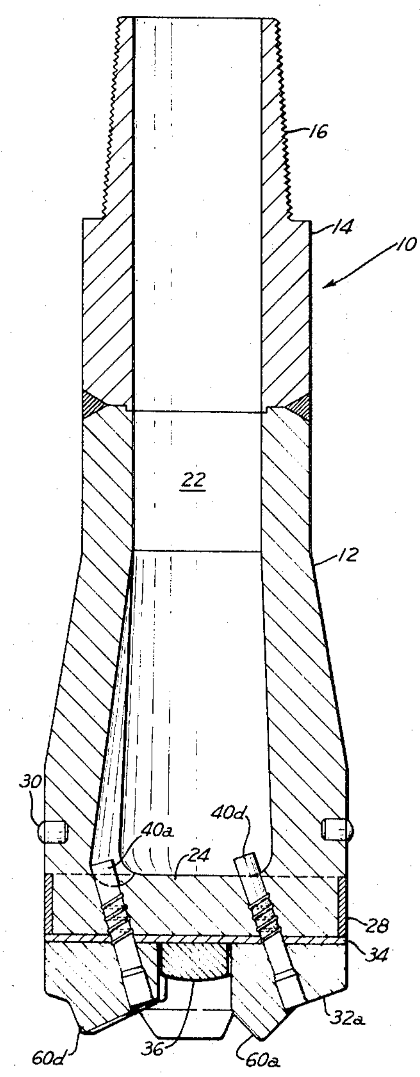
[57] **ABSTRACT**

A drill bit for abrasive jet drilling of wells having a plurality of nozzles extending through the bottom of the bit in position to discharge high velocity jet streams that erode a plurality of concentric grooves in the bottom of the borehole. Each of a plurality of generally sectorially shaped face plates of abrasive resistant material has a wedge extending over the full width of the face plate positioned to ride on the ridge on each side of a groove cut by the stream discharged from a nozzle in a different face plate.

6 Claims, 7 Drawing Figures



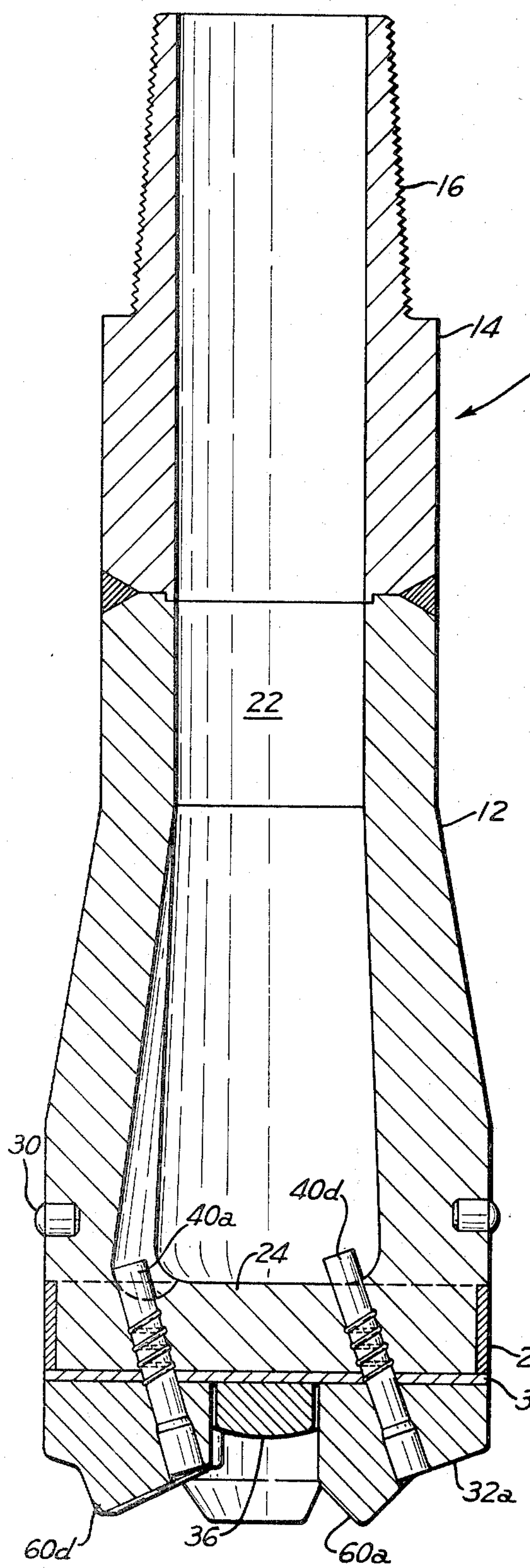

16
14
10
22
12
30
40a
40d
24
28
34
32a
60d
36
60a

Fig.1

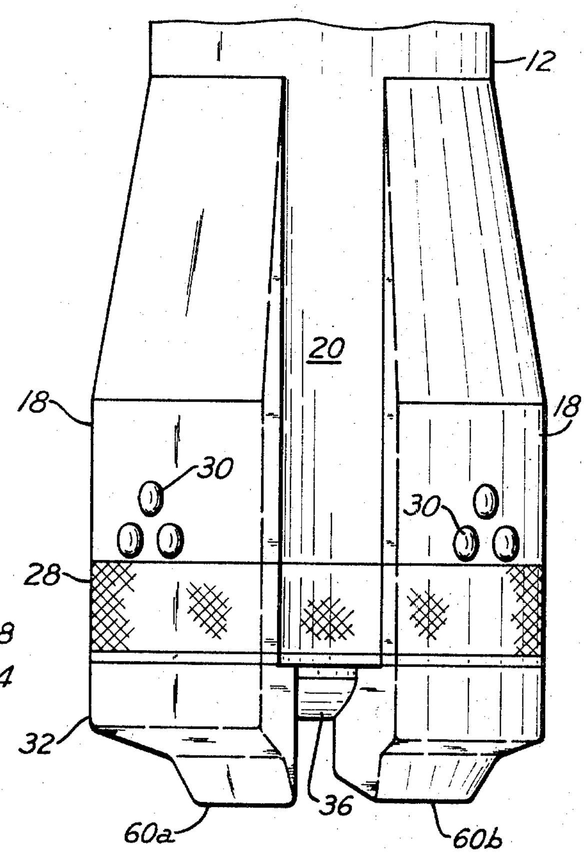

12
20
18
18
30
30
28
32
36
60a
60b

Fig.2

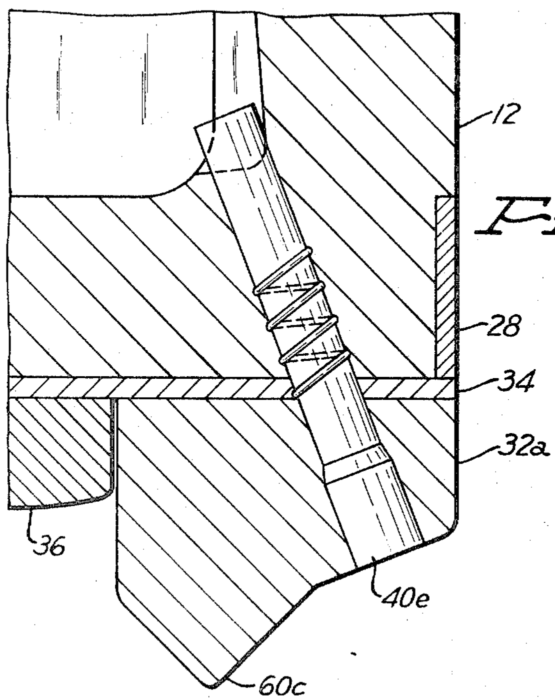


Fig. 4

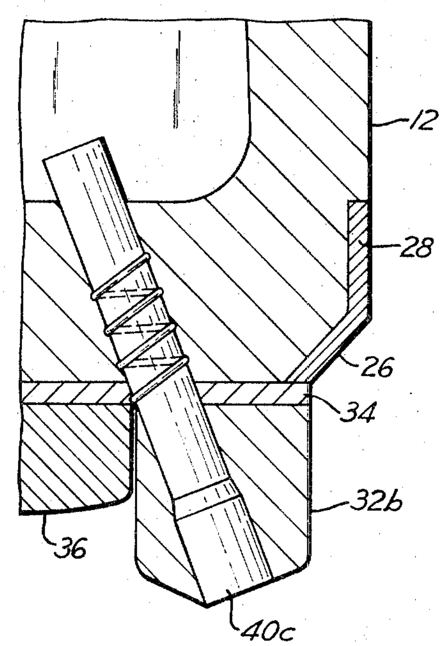


Fig. 5

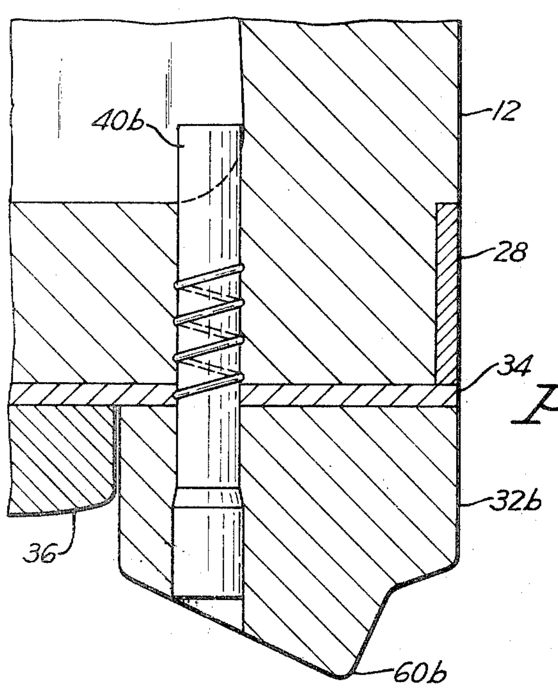


Fig. 6

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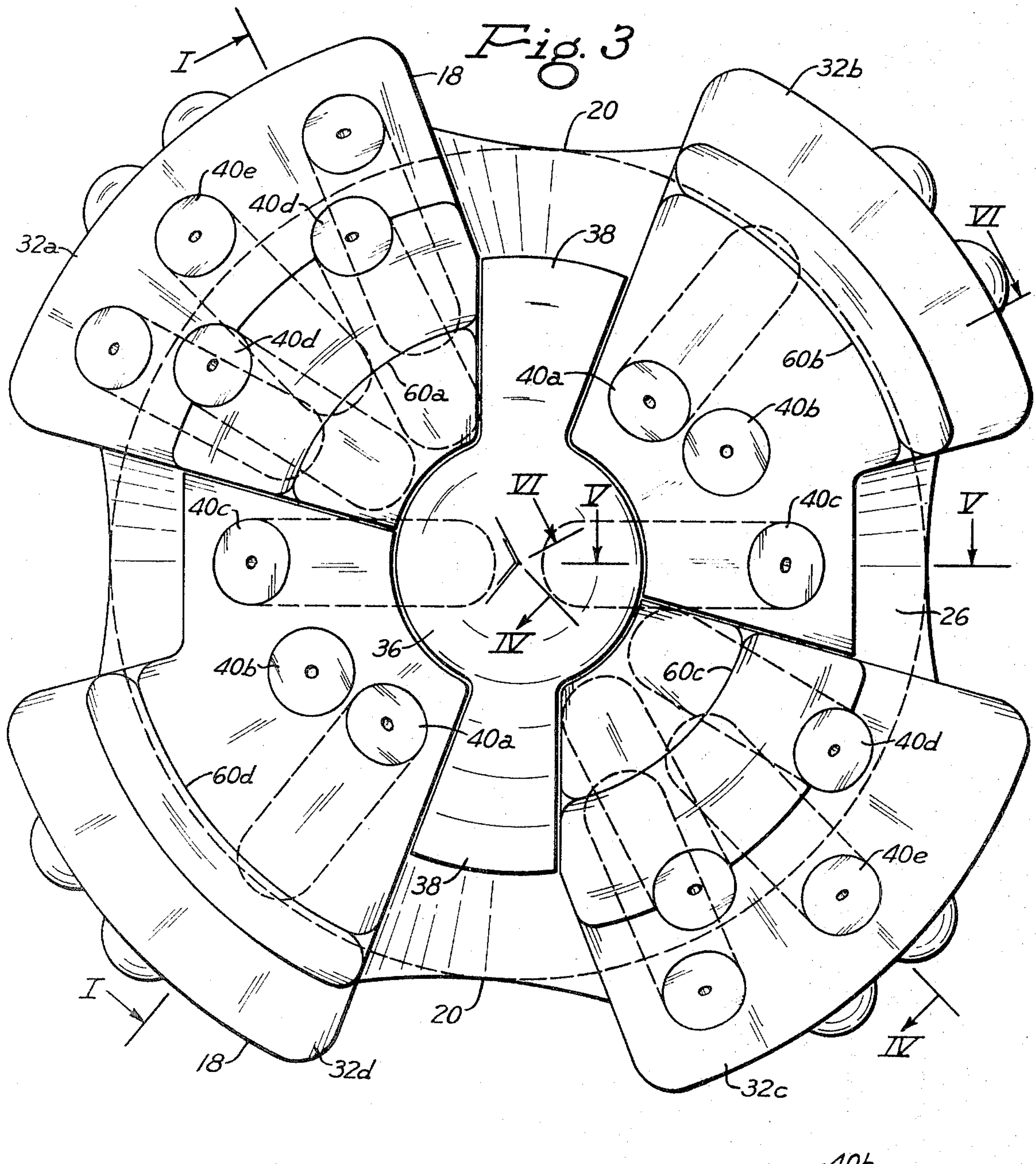

Fig. 3

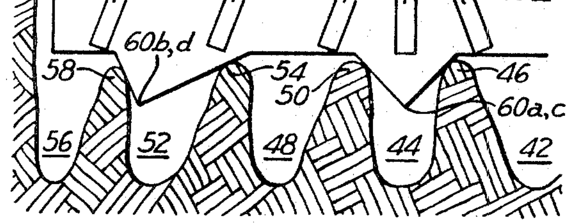

Fig. 7

DRILL BIT FOR ABRASIVE JET DRILLING

This invention relates to the drilling of wells and more particularly to a drill bit for use in abrasive jet drilling.

Abrasive jet drilling has recently been developed for drilling wells through very hard formations in which the drilling rate that can be obtained using conventional rotary drilling operations is so slow that the cost of drilling by such methods becomes excessive. In the abrasive jet drilling process, an abrasive such as steel particles is suspended in a liquid that is pumped down through the drill string and discharged from nozzles in a bit at the lower end of the drill string. The abrasive laden liquid is discharged at a high velocity such as may be obtained by a pressure drop of 5,000 to 10,000 psi, or even more, through the nozzles. The nozzles are positioned in the lower end of the drill bit such that the abrasive laden streams cut in the bottom of the borehole a plurality of concentric grooves separated by thin, easily broken ridges. The ridges separating the grooves are thin mechanically broken by engagement with the drill bit.

In U.S. Pat. No. 3,542,142 of Hasiba et al. a drill bit for abrasive jet drilling is disclosed in which tapered buttons of a wear resistant material such as tungsten carbide extend from the lower end of the drill bit in position to ride on ridges separating the grooves and break the ridges. Similar means for breaking the ridges are disclosed in U.S. Pat. No. 3,548,959 of Hasiba. Tungsten carbide, while necessary to withstand the high erosive conditions below the drill bit, is relatively weak in tension and brittle, and it has been found that the buttons are frequently broken during use of the drill bit. Since mechanical breaking of the ridges is essential to rapid drilling, failure of the buttons will necessitate replacement of the drill bit.

This invention relates to a drill bit for abrasive jet drilling in which a plurality of face plates of generally sectorial shape cover the lower end of the drill bit. The face plates are separated by passages to permit flow of drilling liquid and cuttings from below the bit. Nozzles extending through the lower end of the bit and face plates are positioned to discharge high velocity streams of abrasive laden drilling liquid that cut in the bottom of the borehole a plurality of concentric grooves, the largest of which is around the perimeter of the borehole. The grooves are separated by thin, easily broken ridges. The lower surface of the face plates includes an arcuate wedge extending over the full width of the face plates in a position to extend into alternate grooves cut in the bottom of the borehole and ride on the ridges separating the grooves to mechanically break those ridges. In the preferred embodiment of this invention, the wedge on a face plate extends into grooves cut by abrasive streams discharged from nozzles that have their outlet opening through a different face plate.

In the drawings:

FIG. 1 is a vertical sectional view taken along section line I—I in FIG. 3 of a drill bit constructed in accordance with this invention.

FIG. 2 is an elevation view of the lower portion of the drill bit body.

FIG. 3 is a plan view of the bottom of the bit showing the position of the nozzles and arcuate wedges.

FIG. 4 is a vertical sectional view along the section line IV—IV in FIG. 3.

FIG. 5 is a vertical sectional view, similar to FIG. 4, along the section line V—V in FIG. 3.

FIG. 6 is a vertical sectional view along the section line VI—VI in FIG. 3.

FIG. 7 is a diagrammatic representation of the bottom of the borehole in cross section showing the relative positions of nozzles and wedges with respect to grooves cut in the bottom of the borehole.

Referring to FIG. 1, a drill bit indicated generally by reference numeral **10** is shown having a drill bit body **12** connected at its upper end to an adaptor **14** provided with threads **16** for connection to the lower end of a drill string, not shown. The drill bit **10** is of generally tubular shape open at its upper end to receive drilling liquid from the drill string. As is best shown in FIG. 2, the outer surface of drill bit body **12** has a plurality of spaced apart lobes **18** separated by flutes **20** which provide passages between the drill bit body **12** and the borehole wall for the flow of drilling liquid and cuttings as hereinafter described.

Extending downwardly through the drill bit **10** is a central passage **22** which is closed at the lower end of the drill bit by a bottom **24.** In the construction of the drill bit of this invention, the drill bit body **12,** for example, can be formed by drilling central opening **22** and machining flutes **20** in a solid piece of steel or can be cast in a single piece of the desired shape. The lower surface of the bottom **24** of the drill bit body is flat except for tapered surfaces **26** between the lower ends of lobes **18** and extending along the lower surface of the bottom to the flutes **20** as is shown in FIGS. 3 and 5. The outer surface of the lower end of the drill bit body and the tapered surfaces **26** preferably are covered by hard surfacing material **28** to reduce wear of the drill bit body by rebounding abrasive particles. Wear buttons **30** of an abrasion resistant material, preferably a tungsten carbide alloy, protrude from the outer surface of the drill bit body **12** to protect the drill bit from abrasion by the borehole wall and to break ridges that may protrude from the borehole wall.

Secured to the bottom **24** under each of the lobes **18** is a face plate **32** of an abrasion resistant material such as a tungsten carbide alloy and of generally sectorial shape. A preferred method of attaching the face plates **32** is to silver solder a copper plate **34** to the bottom surface of the bottom member **24** and silver solder the tungsten carbide face plates to the copper plate.

Referring to FIG. 3 of the drawings, it will be noted that in the embodiment of the invention illustrated there are four lobes; however, the number of lobes may be larger or smaller and will depend on the size of the drill bit. The inner end of each of the radii defining the sides of the face plate is spaced from the center of the bit to provide space for a center protector **36** which tapers from a maximum thickness at the center of the bit to a minimum thickness at its outer ends, as is best shown in FIG. 2, to provide channels between the face plates for flow of drilling liquid and cuttings outwardly to the space between flutes **20** and the borehole wall. The center protector **36** illustrated in FIG. 3 has wings **38** extending laterally outward from the center of the bit toward two flutes **20** to provide protection for the bottom of the drill bit body **12** from the abrasion by cuttings and drilling liquid flowing toward the flutes. Center protector **36,** like other parts of the drill bit exposed to rebounding abrasive particles is constructed of an abrasive-resistant material, preferably a tungsten carbide alloy.

As shown in FIG. **1**, the upper ends of a plurality of nozzles generally identified by reference numeral **40**, open into the central opening **22** in the drill bit body. The nozzles **40** extend through bottom **24** and face plates **32** with the lower ends of the nozzles substantially at the bottom surface of the face plates. The nozzles are constructed of an abrasion resistant material, preferably a tungsten carbide alloy, to withstand the severely erosive conditions caused by the very high velocity stream of abrasive laden liquid passing through the nozzle. In the preferred embodiment illustrated in the drawings, nozzles are positioned to cut a central hole surrounded by a plurality of grooves, the outermost of which has an outer diameter equal to the borehole diameter. The central hole may have a center portion extending upwardly from the bottom as a result of the hole being cut by an outwardly slanting nozzle, but the upwardly extending portion should have its upper end eroded by an abrasive jet stream to such an extent that mechanical breaking of the center portion is easy or is not necessary. Thus, in referring to cutting a central hole it is meant that an abrasive jet stream cuts a hole that leaves little if any rock at the center of the borehole to be mechanically broken by the drill bit.

Referring to FIG. **3** and FIG. **1**, inwardly directed nozzles **40***a* discharge a stream to cut a central hole **42** (shown in FIG. **7**) in the bottom of the borehole. Verticle nozzles **40***b* shown in FIGS. **3** and **6** discharge high velocity streams of abrasive laden liquid to cut a groove **44** separated from central hole **42** by a ridge **46.** Outwardly slanting nozzles **40***c* shown in FIGS. **3** and **5** discharge streams that cut a groove **48** separated from groove **44** by ridge **50.** Nozzles **40***d* shown in FIGS. **3** and **1** are positioned and slope outwardly to discharge a stream that cuts a groove **52** separated from groove **48** by ridge **54.** Nozzles **40***e* shown in FIG. **3** and FIG. **4** slope outwardly and are positioned to discharge abrasive laden streams that cut groove **56** separated from groove **52** by ridge **58.** The outer wall of groove **56** is the borehole wall. Because of the greater amount of rock that must be removed to cut the grooves of larger diameter, the number of nozzles at a particular distance from the center of the bit increases as the distance from the center increases. Thus, there are in the embodiment shown five nozzles **40***e* and four nozzles **40***d*. Two each of nozzles **40***a*, **40***b* and **40***c* are provided. Although a single nozzle would be adequate to remove the rock in the central hole, two nozzles are provided as insurance against the possibility of a single nozzle becoming plugged. The nozzles **40** can be held in position in the openings through bottom **24** and face plates by helical coils engaging grooves in the outer surface of the nozzles and in the wall of the openings, as disclosed in U.S. Pat. No. 3,688,852.

In the embodiment illustrated in FIG. **3** of the drawings, the face plates **32** differ slightly in configuration because of the difference in location and orientation of the nozzles extending through the face plates for discharge of high velocity streams of drilling liquid against the borehole bottom. The upper left-hand face plate, designated as **32***a*, has three nozzles **40***e* and two nozzles **40***d* extending through it. The face plate at the upper right-hand portion of FIG. **3** is designated **32***b*. Nozzles **40***a*, **40***b* and **40***c* extend through that face plate. The face plate at the lower right portion of FIG. **3** is designated **32***c*. Two nozzles **40***e* and two nozzles **40***d* extend through that face plate. At the lower left portion of FIG. **3** the face plate is designated as **32***d* to facilitate description of this invention. Face plate **32***d* is identical to face plate **32***b* except for its position on the bottom of the drill bit.

Extending downwardly from each of the face plates is an arcuate wedge identified generally by numeral **60** positioned to extend into a groove cut in the bottom of the borehole and ride on the ridges forming the side walls of the groove. Arcuate wedges **60** extend over substantially the full width of the face plates to a level below the outlet ends of the nozzles. The term "full width" means that the arcuate wedge extends substantially from the radius defining one side of the face plate to the radius defining the opposite side. The center of curvature of the wedges is the center of rotation of the drill bit.

The wedge extending downwardly from the lower surface of face plate **32***a* is designated **60***a* and is best shown in FIGS. **1** and **3** of the drawings. Wedge **60***a* is positioned to extend into grooves **44** and ride on ridges **46** and **50.** A wedge **60***b* on face plate **32***b* extends downwardly in position to extend into groove **52** and ride on ridges **54** and **58.** Wedge **60**c on the lower surface of face plate **32***c* is positioned at the same radial distance from the center of rotation of the drill bit as wedge **60***a* and is adapted to extend into groove **44** and ride on ridges **46** and **50.** Wedge **60***d* is at the same radial distance from the center of rotation of the bit as **60***b* and therefore extends into groove **52** and rides on ridges **54** and **58.** It is an advantage of this invention that the wedges on the bottom of a face plate extend into grooves cut by high velocity streams discharged from nozzles that extend through a different face plate. Thus, none of the wedges is subjected to severe erosion by rebounding abrasive particles moving at high velocity discharged from a nozzle close to, or having its outlet in, the wedge.

In use, the drill bit is secured to the lower end of the drill string and lowered into the hole. Drilling liquid containing abrasive particles suspended therein is pumped down the drill string as the drill string is rotated. The pressure on the drilling liquid is such that the drilling liquid is discharged from the nozzles at a velocity of at least 650 feet per second.

The high velocity streams of drilling liquid discharged from the nozzles cut the central hole and the grooves **44, 48, 52** and **56** shown in FIG. **7** in the bottom of the borehole. The arcuate wedges **60***a* and **60***c* on face plates **32***a* and **32***c* extend into the upper end of the groove **44** and ride on ridges **46** and **50.** Arcuate wedges **60***b* and **60***d* extend into grooves **52** and ride on ridges **54** and **58.** It is only necessary that wedges extend into alternate grooves to subject each of the ridges **46, 50, 54** and **58** to mechanical stress by an arcuate wedge extending from the face plate of the drill bit.

Weight of approximately 1,000 lbs. per inch of diameter of the drill bit placed on the drill bit is adequate to break the ridges extending upwardly from the bottom of the borehole. Rock broken from the ridges and eroded from the bottom by the abrasive stream is swept away by drilling liquid discharged from the nozzles and is carried upwardly between the outer surface of the bit and the borehole wall into the annulus surrounding the drill string. The flutes in the lateral surface of the bit and the passages between the face plates facilitate flow of cuttings from the bottom of the borehole.

The single wedge in each of the face plates provides a massive element capable of withstanding impact placed on the wedges. The substantial length of the wedges increases the stability of the bit as it rotates at the bottom of the hole. The positioning of wedges in one face plate to extend into grooves cut by nozzles that extend through a different face plate eliminates weakening of the wedges by holes for nozzles. By providing a single wedge in each of the face plates, interference with movement of particles broken from the ridges by the arcuate wedges is reduced to a minimum. Moreover, tensile stresses that might be developed by one wedge in a single face plate being forced outwardly while another is forced inwardly is avoided. Since tungsten carbide is relatively weak in tension, although highly resistant to abrasion, a single arcuate wedge in a face plate greatly reduces the chances of breaking the wedge from the face plate.

I claim:

1. A drill bit adapted to be rotated by a drill string about a central axis for abrasive jet drilling comprising a hollow body closed at the lower end and adapted at its upper end for connection to the lower end of the drill string, a plurality of face plates of abrasive resistant material and generally sectorial shape extending from the lower end of the drill bit body, outlet passages between adjacent face plates for removal of cuttings from below the bit, a plurality of nozzles extending downwardly through the lower end of the bit and the face plates positioned to cut in the bottom of the hole being drilled a plurality of concentric grooves separated by ridges, and each of the face plates having an arcuate wedge extending downwardly over the full width of the face plates positioned to extend into a groove and ride on ridges forming the sides of the groove to break the ridges, said arcuate wedge having a center of curvature substantially at the axis of rotation of the drill bit.

2. A drill bit as set forth in claim **1** in which the nozzles cut a central hole that is surrounded by the concentric grooves.

3. A drill bit as set forth in claim **1** in which the wedges of each face plate are positioned to extend into grooves cut by the discharge of abrasive laden liquid through nozzles in a different face plate.

4. A drill bit as set forth in claim **3** in which there are four face plates and the wedges on opposite face plates are at the same radial distance from the axis of rotation of the drill bit.

5. A drill bit as set forth in claim **1** in which there are four face plates, the nozzles extending through the lower end of the drill bit are positioned to cut a central hole surrounded by four concentric grooves and the wedges extending from two opposite face plates ride on the ridges separating the first and second grooves and the ridge separating the second groove and the third groove and wedge extending from the other face plates ride on the ridge separating the third and fourth groove and on the ridge separating the fourth groove and the central hole.

6. A drill bit as set forth in claim **1** in which wedges are positioned to extend into alternate grooves whereby each ridge is engaged by at least one wedge.

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