# United States Patent

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[54] **RELIEF-TYPE JET BITS**
**11 Claims, 8 Drawing Figs.**


[52] **U.S. Cl.** .......... **175/393,** 175/410, 175/422
[51] **Int. Cl.** .......... **E21c 15/00,** E21c 13/01; E21b 7/18
[50] **Field of Search** .......... 175/380, 422, 393, 409, 410, 417, 418



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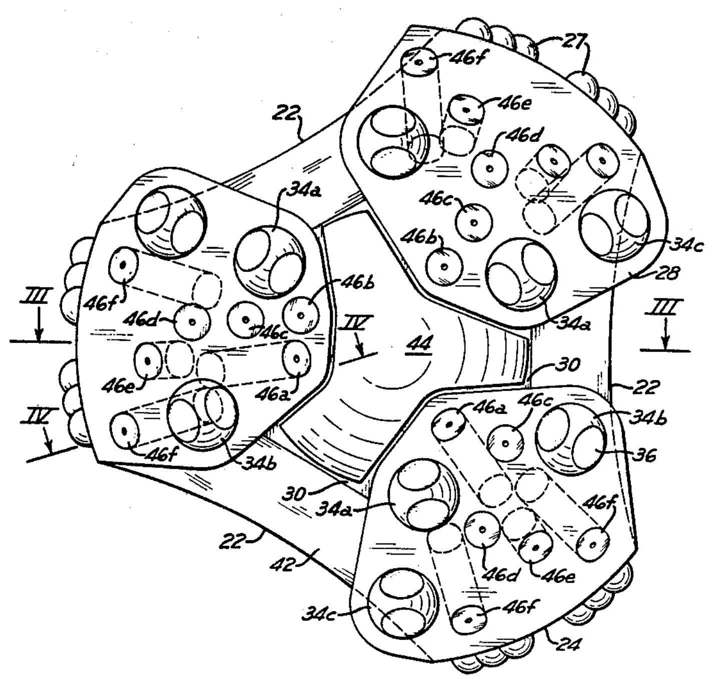
**ABSTRACT:** A drill bit for hydraulic jet drilling in which a plurality of plateaus extend forwardly from the working end of the bit. Nozzles extending through the forward end of the bit for the discharge of an abrasive-laden drilling liquid have their outlets in the plane of the plateaus. The plateaus are separated by relief channels which provide space for the escape of large particles of the material drilled. The bit preferably has a non-round shape to provide large passages between the bit and the wall of the hole drilled.

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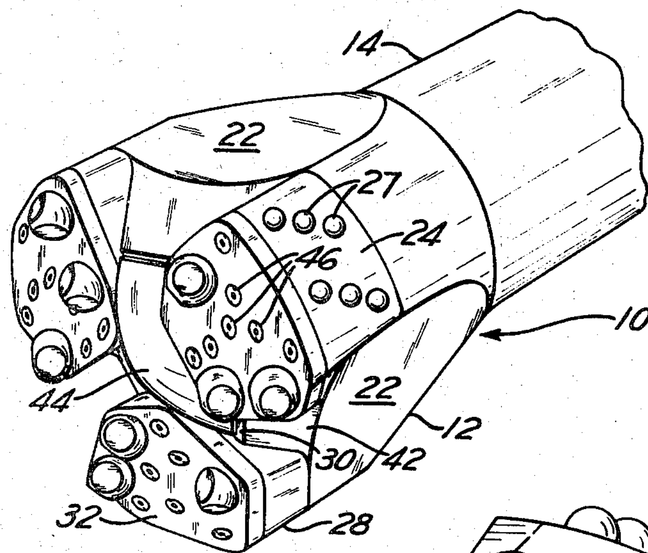


Fig. 1

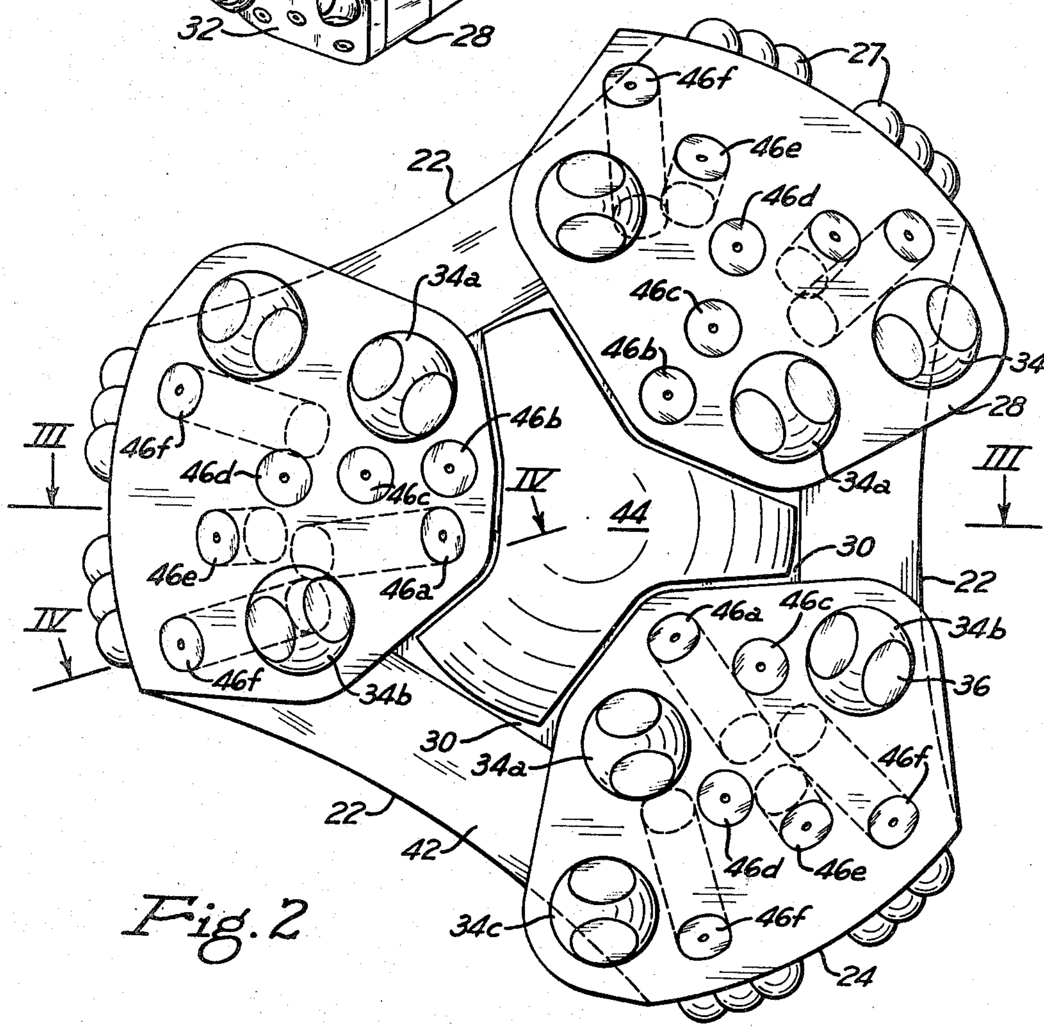


Fig. 2

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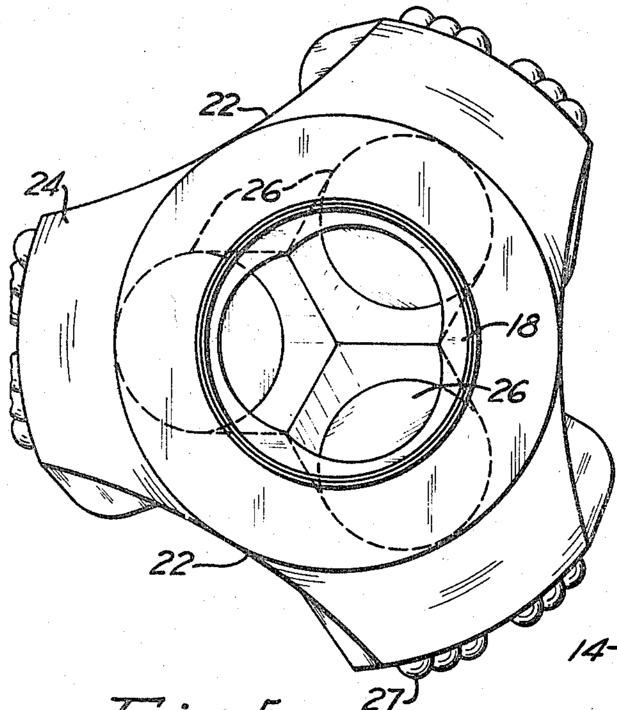
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Fig. 5

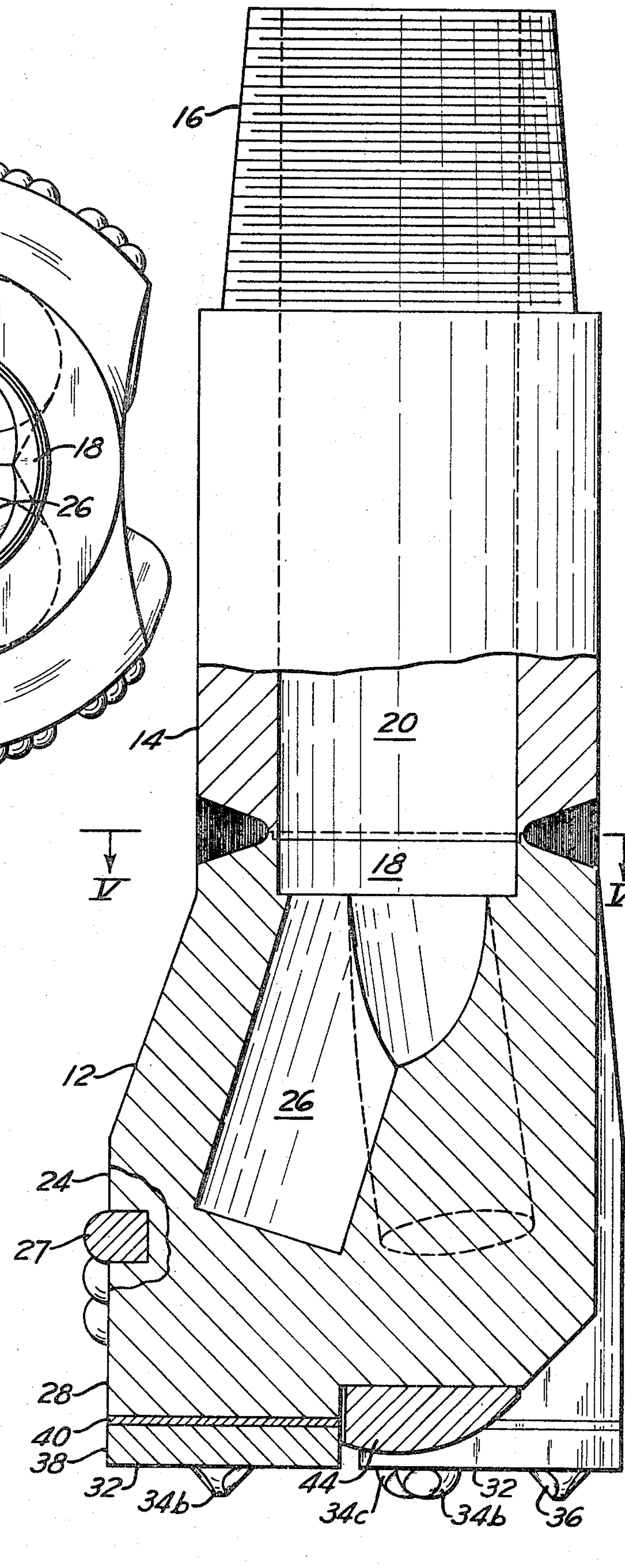
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Fig. 3

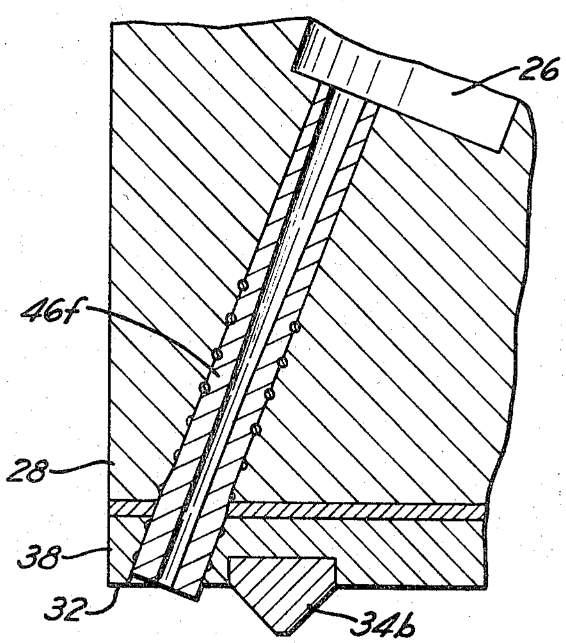


Fig. 4

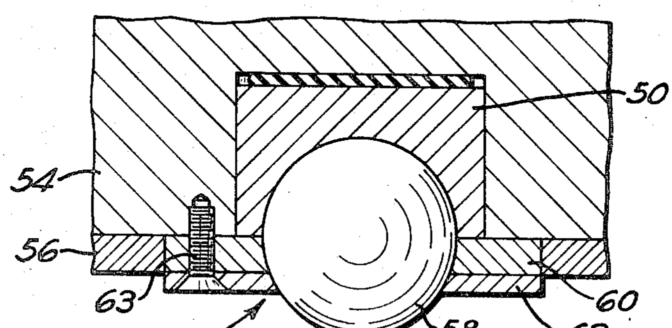


Fig. 8

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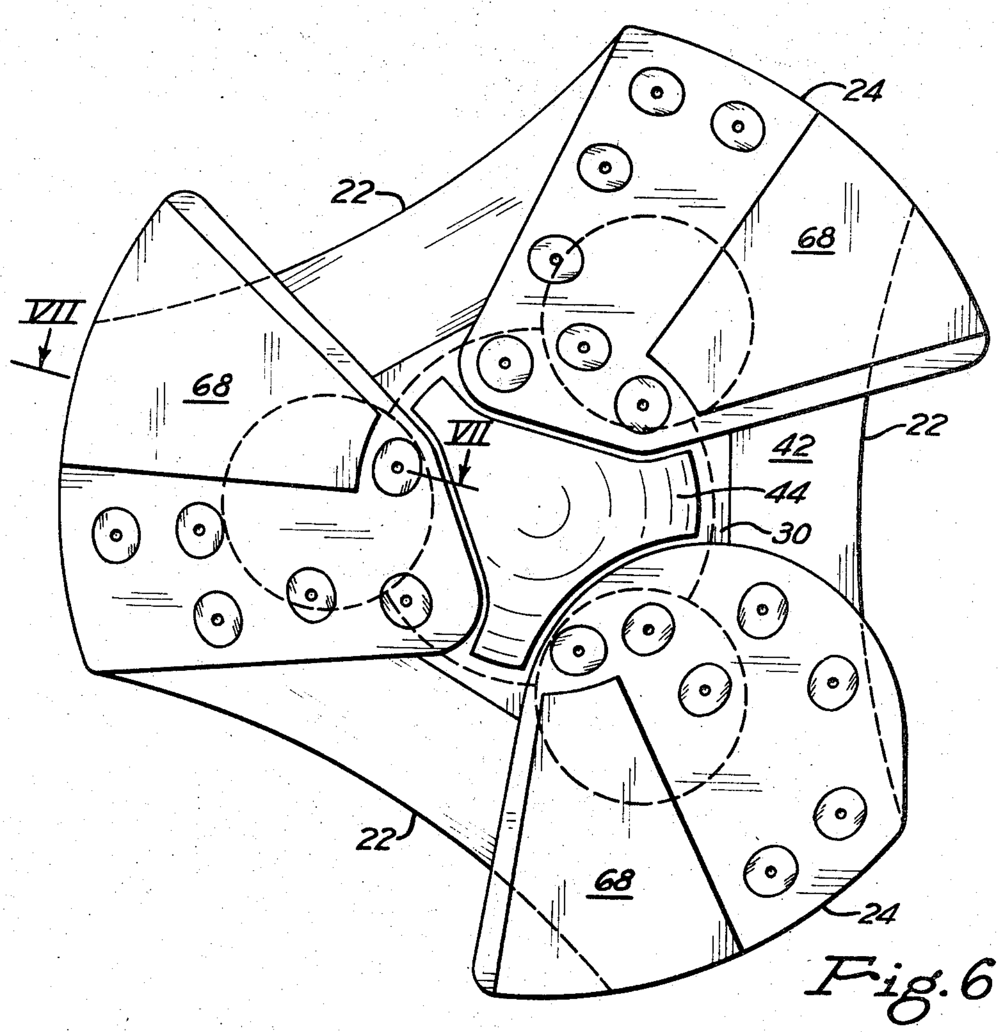


Fig. 6

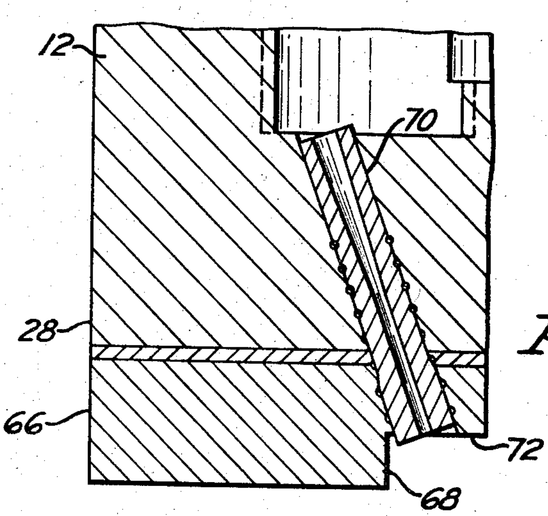


Fig. 7

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## RELIEF-TYPE JET BITS

This invention relates to drilling and more particularly to a drill bit for hydraulic jet drilling in which penetration of the material drilled is by means of high-velocity streams of abrasive-laden liquid.

In the conventional rotary drilling process, a drill bit mounted on the lower end of a drill stem is rotated against the bottom of the borehole while a fluid, usually a drilling mud, is circulated down the hole on one side of the drill stem and up the hole on the other side to remove cuttings from the hole. Ordinarily the drilling mud is circulated down through the drill stem, out through nozzles in the drill bit, and up through the annulus between the drill stem and the borehole wall. The drill bit penetrates the rock being drilled by mechanically breaking particles of rock from the bottom of the hole.

The rotary drilling process has been highly successful in drilling soft formations and formations of medium hardness, but has not been as successful in drilling hard formations. In addition to causing a lower rate of penetration, hard formations cause rapid wear of the drill bits and make necessary frequent round trips to replace the bit. The lost drilling time during the round trips increases the time a drilling rig must stay at the well site and thereby increases the cost of drilling.

One method that has been developed recently for the drilling of hard formations is the hydraulic jet-drilling process. In that process the bottom of the borehole is eroded by a plurality of streams of an abrasive-laden liquid discharged at extremely high velocity from nozzles in a drill bit connected to the bottom of a rotating drill stem. In a preferred hydraulic jet-drilling method, the streams of abrasive-laden liquids cut a central hole and a plurality of concentric grooves in the bottom of the borehole and the drill bit engages the ridges separating the grooves to break large particles of rock from the bottom of the borehole and thereby increase the drilling rate. Although the hydraulic jet-drilling method has shown advantages over conventional rotary drilling resulting from increases in rate of penetration and reduction in wear of the drill bit, further increases in the drilling rate are desirable to reduce the cost of drilling.

This invention resides in a drill bit for use in the hydraulic jet-drilling process having a hollow body closed at its forward end and adapted to be connected to the end of a drill stem. The forward surface of the drill bit is characterized by three different levels. A recessed level at the greatest distance from the material being drilled comprises relief channels that separate plateaus of generally sectorial-shape at an intermediate level, referred to as the nozzle outlet plane, forward of the relief channels. Extending forwardly from the plateaus are standoff elements adapted to engage the end of the borehole and fix the distance of the nozzle outlet plane from the end of the borehole. Nozzles extending from the space within the hollow drill bit body forwardly through the closed forward end of the drill bit have their outlets in the nozzle outlet plane. In a preferred embodiment of the invention, the standoff elements, which may be either rotatably mounted or stationary, act as wedges riding in grooves cut by the high-velocity streams applying a lateral force against the ridges separating the grooves. The term forward is used to designate the direction of penetration during the drilling while the term recessed designates the opposite direction.

Referring to the drawings:

FIG. 1 is a perspective view of a drill bit constructed in accordance with this invention.

FIG. 2 is a plan view of the forward end of the drill bit showing the location and orientation of the nozzles through which the abrasive-laden drilling liquid is discharged and of the standoff elements.

FIG. 3 is a longitudinal sectional view of the drill bit illustrated in FIGS. 1 and 2 taken along the section line III–III in FIG. 2.

FIG. 4 is a vertical sectional view along section line IV–IV in FIG. 2 showing in section a nozzle and standoff element.

FIG. 5 is a horizontal sectional view of the drill bit body taken along section line V–V in FIG. 3.

FIG. 6 is a plan view of the forward end of an embodiment of this invention having flat standoff elements extending forwardly from the face plates mounted on the closed forward end of the drill bit.

FIG. 7 is a vertical sectional view along section line VII–VII in FIG. 6 showing one of the nozzles and standoff elements in section.

FIG. 8 is a vertical sectional view showing a structure for rotatably mounting a standoff element.

Referring to FIG. 1 in the drawings, a drill bit indicated generally by reference numeral 10 is illustrated having a drill bit body 12 welded at its upper end to a tubular shank 14. For purposes of description, this invention is described with reference to a drill bit for drilling the borehole of a well. Since normal drilling of a well is downward, the forward direction is downward. As shown in FIG. 3, shank 14 is provided at its upper end with a threaded pin 16 for connection to the lower end of a drill stem. Drill bit body 12 has a central opening 18 that communicates with a central opening 20 in the shank for delivery of drilling liquid into the drill bit. As is best shown in FIGS. 1 and 2, the drill bit body 12 has flutes 22 on its outer surface to provide passage for drilling liquid and cuttings between the outer surface of the drill bit and the borehole wall. Flutes 22 are separated by lobes 24 that form a drill bit of the desired diameter. Flutes 22 are shown in the drawings as being convex. Although that is the preferred shape, the flutes could be flat or even convex with a larger diameter of curvature than the lobes to provide space between the outer surface of the flutes and the borehole wall. Buttons 27 of an abrasion-resistant material such as a tungsten carbide alloy extend outwardly from the lobes to center the bit in the borehole. It is preferred that the outer faces of the lobes be faced with a hard metal to reduce erosion by rebounding abrasive particles. The drill bit body 12 has counterbores 26 drilled downwardly and outwardly from central opening 18 to provide passages into the lobes 24 for the delivery of drilling liquid to the nozzle inlets.

Protruding downwardly from the lower end of the drill bit below the lobes 24 are spaced plateaus 28 separated by recessed relief channels 30. Recessed relief channels 30 extend generally radially from the center of the bottom of the drill bit toward the flutes 22. Near the outer end of the relief channels, 30, the bottom of the drill bit is beveled at 42 to increase the size of the relief channels and provide a less abrupt change in direction from the relief channels into the space provided by the flutes. Standoff elements 34 extend downwardly from the lower surface 32 of the plateaus 28 to engage the bottom of the borehole and support the drill bit with lower surface 32, the nozzle outlet plane, the desired distance above the bottom of the borehole. Plateaus 28 are from ¾ inch to 1½ inches below the recessed relief channels 30, and the lower end of the standoff elements extend ¼ inch to 1¼ inches below the lower surface 32. The standoff elements 34 illustrated in FIGS. 1 through 5 are of the button-type and consist of generally hemispherical members having oppositely directed planar surfaces 36 facing in the direction of the radius of the bit.

Plateaus 28 are of a hard, abrasion-resistant material such as a tungsten carbide alloy to avoid excessive erosion by rebounding abrasive particles. The plateaus can be constructed by securing a face plate 38 of tungsten carbide alloy to the lower surface of the lower end of the drill bit directly below the lobes 24. A preferred method of securing the face plate 38 to the lower surface of the lower end of the drill bit body 12 is by silver soldering a copper sheet 40 to the lower surface of the lower end of the drill bit and silver soldering the face plate 38 to the copper sheet 40. Standoff elements 34 are also constructed of an abrasion-resistant material such as tungsten carbide and are secured in place by silver soldering in sockets in the face plate 38 as shown in FIG. 4.

A protector 44 illustrated in vertical section in FIG. 3 of the drawings is secured, for example by brazing, to the recessed area of channels 30. Protector 44 is tapered such that it blends into the bottom surface at bevel 42 to provide a smooth flow pattern minimizing turbulence. The thickness of the protector decreases from a maximum at the center of the drill bit such that the lower surface of the protector at the center is at a slightly higher level than the lower surface 32 of the plateaus 28 to a minimum at its periphery. The protector 44, which is constructed of tungsten carbide, shields the steel drill bit body 12 and copper plate 40 from erosion by rebounding particles of abrasive.

As best shown in FIGS. 1, 2 and 4, a plurality of nozzles, indicated generally by reference numeral 46, extend downwardly through the lower end of the drill bit body 12 and terminate with their outlets in the plane of the lower surface 32 of plateaus 30. The number and position of the nozzles 46 are dependent upon the size of the drill bit, the capacity of the pump used to deliver drilling liquid to the drill bit, and the arrangement and type of standoff elements. It is desirable that the nozzles be positioned and sufficient in number to cut a central hole and a plurality of concentric grooves separated by intervening ridges of a width such that they can be easily broken by a light load on the drill bit. Nozzles 46 have an outlet diameter of 3/32 to 3/16 inch and are constructed of an abrasion-resistant material such as tungsten carbide.

In the drill bit illustrated in FIG. 2 of the drawings, inwardly sloping nozzles 46*a* are provided to cut a central hole in the bottom of the borehole directly below the protector 44. Proceeding outwardly from the center of the bit, there are successive series of vertical nozzles 46*b*, vertical nozzles 46*c*, vertical nozzles 46*d*, sloping nozzles 46*e* and sloping nozzles 46*f*. The series of nozzles 46*f* slopes outwardly at an angle such that the high-velocity stream of drilling liquid discharged from that series of nozzles strikes the bottom of the borehole to cut a groove having an outside diameter equal to the desired borehole diameter. Jets from nozzles 46*f* cut a groove having an outer diameter permitting the bit to descend easily. Buttons 27 break off rock projecting from the borehole wall that may not have been removed by the jets from nozzles 46*f*. Such projections are rare; the buttons 27 serve primarily to center the bit in the hole. Because the amount of rock cut from the bottom of the borehole to cut a groove of a given depth increases with the distance from the center of the borehole, the number of nozzles in each series increases as the distance of the nozzle from the center of the bit increases. For example, in the bit illustrated in FIG. 2, two nozzles 46*a* and two nozzles 46*b* are provided. Although one of each of the nozzles might be sufficient, it is desired to provide two to avoid leaving a central core at the bottom of the borehole if one nozzle in the series should become plugged. Three nozzles 46*c* and 46*d*, four nozzles 46*e* and six nozzles 46*f* are provided.

The standoff elements 34 are positioned to ride in the grooves cut by the high-velocity streams discharged from the nozzles and apply a compressive load to the ridges separating the grooves. The tapering of the standoff elements causes them to exert the compressive force on the ridges eccentrically and thereby place part of the rock in the ridges in tension to aid in breaking the rock. For example, in FIG. 2 standoff elements 34*a* are the same distance from the center of the drill bit as nozzles 46*c* and ride in the groove cut by the drilling liquid discharged from those nozzles. Standoff elements 34*b* are the same distance from the center of the drill bit as nozzles 46*d* and ride in the groove cut by the high-velocity stream of drilling liquid discharged from those nozzles. Because the nozzles 46*e* slant outwardly, the grooves cut by the drilling liquid discharged from those nozzles are not directly below the nozzle outlets. Standoff elements 34*c* are slightly farther than nozzles 46*e* from the center of the drill bit, and are positioned to ride in the groove cut by the high-velocity stream discharged from those nozzles.

In the operation of the drill bit of this invention, the drill stem is rotated and a drilling liquid having abrasive particles, such as 10 to 80 mesh ferrous shot or grit, suspended in it is pumped down the drill stem and into the drill bit 10. The drilling liquid flows through central opening 20 into counterbores 26 and is discharged through the nozzles 46. The drilling liquid is under a pressure of 4000 p.s.i. or more to impart a velocity of at least 650 feet per second to the drilling liquid discharged from the nozzles. As the drill bit rotates with the drill stem, the drilling liquid discharged from nozzles 46*a* cuts a central hole below the protector 44 and flows outwardly through relief channels 30 between the plateaus 28 and the enlarged passages resulting from beveled surfaces 42 to the space provided by the flutes 22 between the drill bit and the borehole wall. The high-velocity stream of drilling liquid discharged from nozzles 46*b* enlarges the central hole while the drilling liquid discharged from nozzles 46*c* cuts a groove spaced from the central hole by a relatively thin, easily broken, intervening ridge. Similarly, the high-velocity streams of liquid discharged from nozzles 46*d*, 46*e* and 46*f* cut a plurality of concentric grooves spaced by intervening ridges. The spacing of the nozzles is such that the intervening ridges have a width less than about ½ inch to allow a relatively small weight on the bit to break the ridges. The standoff elements 34*a*, 34*b* and 34*c* extend downwardly into the grooves, and the faces 36 of the standoff elements apply a lateral force to the ridges between the grooves.

In the drill bit of this invention, the large particles of rock broken from the ridges move into the passages formed by beveled surfaces 42 and flow unimpeded outwardly to the space between the flutes 22 and the borehole wall. The large area available between the beveled surfaces 42 and the bottom of the borehole allows rapid flow of the large particles with a minimum of regrinding of the particles. Because the rock cut and removed by the hydraulic bits alone is very finely divided, ordinarily of the order of 200 mesh, the reduced space between the center of the protector 44 and the nozzle outlet plane does not necessitate regrinding of rock particles. Tests designed to compare the drilling rate of bits having relief channels between the plateaus with bits similar except having a flat bottom from which the standoff elements extend have shown a gain of drilling rate of as much as 40 per cent with bits having relief channels. It is believed that the gain in drilling rate is the result of large rock particles being able to move through relief channels 30 and the enlarged space resulting from beveled surfaces to the flutes; hence, little energy or time is spent in regrinding such particles.

In FIG. 8 of the drawings, a rotatably mounted standoff element 48 that may be used in place of standoff element 34 is illustrated. Standoff element 48 comprises a ball seat 50 mounted in a socket 52 extending inwardly into the lower end of a plateau 54. The lower surface of plateau 54 is covered by a face plate 56. A spherical loading member 58 is rotatably seated on ball seat 50 and held in place by a retaining ring 60, the lower surface of which is covered by a protector plate 62 of abrasive-resistant material. Retaining ring 60 fits in an opening in face plate 56 and is held in place by screws 62. The heads of screws 63 should be of tungsten carbide, or another material of similar properties.

The operation of a bit constructed with the rotatable loading elements in place of elements 34 is similar to the embodiment of the invention illustrated in FIGS. 1 through 5. The rotatable standoff element results in a smoother operation of the drill bit. An advantage of the rotatably mounted standoff elements is that such standoff elements roll on the ridges and thereby avoid much of the alternate heating and cooling of standoff elements that are dragged along the ridges.

In the embodiment of the invention illustrated in FIGS. 6 and 7, the drill bit body 12 is the same as in FIGS. 1 through 5 with flutes 22 separated by lobes 24. The plateaus 28 have face plates 66 secured to their lower surface. Face plates 66 differ from face plates 38 in having a relatively large flat-bottomed standoff element 68 extending downwardly below the lower surface 32 of each of the plateaus. Nozzles 70 extending through the lower end of the drill bit 12 have their outlets in the plane of lower surface 72 of the face plate 66. A protector plate 44 is secured in the central portion of the channels 30 to protect the lower end of the drill bit from erosion by rebounding abrasive particles. The lower end of the drill bit is beveled at **42** between the channels **30** and flutes **22** to facilitate flow of large particles to the space between the flutes **22** and the borehole wall.

The operation of the drill bit illustrated in FIGS. **6** and **7** is similar to the embodiment of the invention illustrated in FIGS. **1** through **5**, with the exception that the standoff elements **68** ride on the upper surface of the ridges separating grooves cut in the bottom of the borehole and apply a compressive load so that there is substantially no wedging action on the ridges between the grooves. The increased clearance between the bottom of the borehole and the lower end of the drill bit resulting from the relief channels **30** allows large particles broken from the ridges to flow outwardly to the annulus between the drill bit and the borehole wall with little, if any, regrinding of the particles.

I claim:

**1.** A drill bit for hydraulic jet-drilling comprising a hollow body closed at its forward end, a plurality of plateaus substantially flat at their forward end extending forwardly from the forward end of the bit, recessed relief channels separating the plateaus and extending outwardly to the periphery of the bit, nozzles for the delivery of drilling liquid extending through the forward end of the bit and having their outlets substantially in the plane of the plateaus, and standoff elements extending forwardly from the plateaus.

**2.** A drill bit as set forth in claim **1** in which flutes extend longitudinally along the outer surface of the drill bit body and the recessed relief channels extend substantially radially on the forward end of the drill bit to the flutes.

**3.** A drill bit as set forth in claim **1** in which the forward surface of the plateaus, the standoff elements, and the nozzles are constructed of an abrasion-resistant material.

**4.** A drill bit as set forth in claim **1** in which the recessed relief channels intersect at a central position in the forward end of the drill bit and extend radially outward to the periphery of the bit to separate plateaus of generally sectorial shape.

**5.** A drill bit as set forth in claim **4** in which a protector plate of abrasion-resistant material covers the relief channels.

**6.** A drill bit as set forth in claim **1** in which the nozzles are positioned to cut an outer groove having an outer diameter larger than the diameter of the drill bit and a plurality of concentric grooves separated by intervening ridges, and the standoff elements are positioned to engage ridges separating the concentric grooves.

**7.** A drill bit as set forth in claim **6** in which the standoff elements taper forwardly and are positioned to extend into the grooves and engage the ridges separating the grooves to exert a radial force on the ridges.

**8.** A drill bit as set forth in claim **6** in which the standoff elements are rotatably mounted.

**9.** A drill bit for hydraulic jet-drilling comprising a hollow drill bit body closed at its forward end and open at the opposite end, flutes extending longitudinally along the outer surface of the drill bit body, lobes separating the flutes, plateaus substantially flat at their forward ends protruding forwardly from the forward end of the drill bit in alignment with the lobes, recessed relief channels intersecting at the center of the forward end of the drill bit and extending substantially radially toward the flutes to separate the plateaus, beveled surfaces extending from the outer ends of the channels to the flutes, nozzles extending through the forward end of the drill bit and terminating at the forward surface of the plateaus, said nozzles being positioned to cut a central hole surrounded by concentric grooves separated by thin easily broken ridges in the material drilled, and standoff elements extending forwardly from the plateaus in position to engage the ridges.

**10.** A drill bit as set forth in claim **9** in which a protector plate of abrasion-resistant material covers the relief channels and tapers from a maximum thickness less than the height of the plateaus at the center of the forward end of the drill bit to blend into the beveled surface between the relief channels and the flutes.

**11.** A drill bit as set forth in claim **9** having a plurality of buttons of an abrasion-resistant material extending laterally from its sides.