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(54) Rotary cone rock bit

(57) A rotary cone rock bit 10 for use in earthen formations utilises diffusion type nozzles 30 which are located at the outer region of a dome portion 40 of the rock bit resulting in a diffused flow 42 of fluid without turbulence leaving the exit end 36 of the nozzle 30. The diffused spray 42 of fluid at a lesser velocity will better clean the rotary cones 22 by moving the fluid closer to the cones without erosive damage to the cones or loss of cutter inserts or milled teeth. The diffused spray will additionally cover a larger area of a borehole bottom resulting in better bottom hole cleaning.

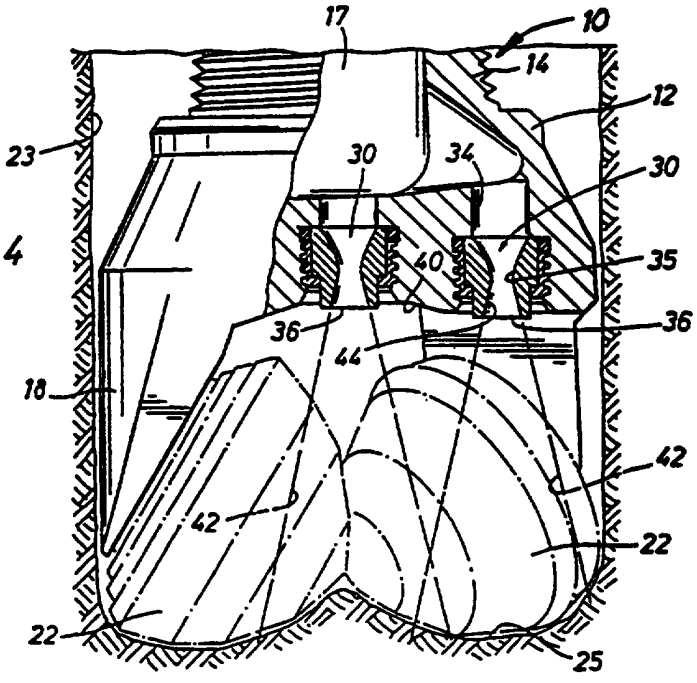

FIG. 4

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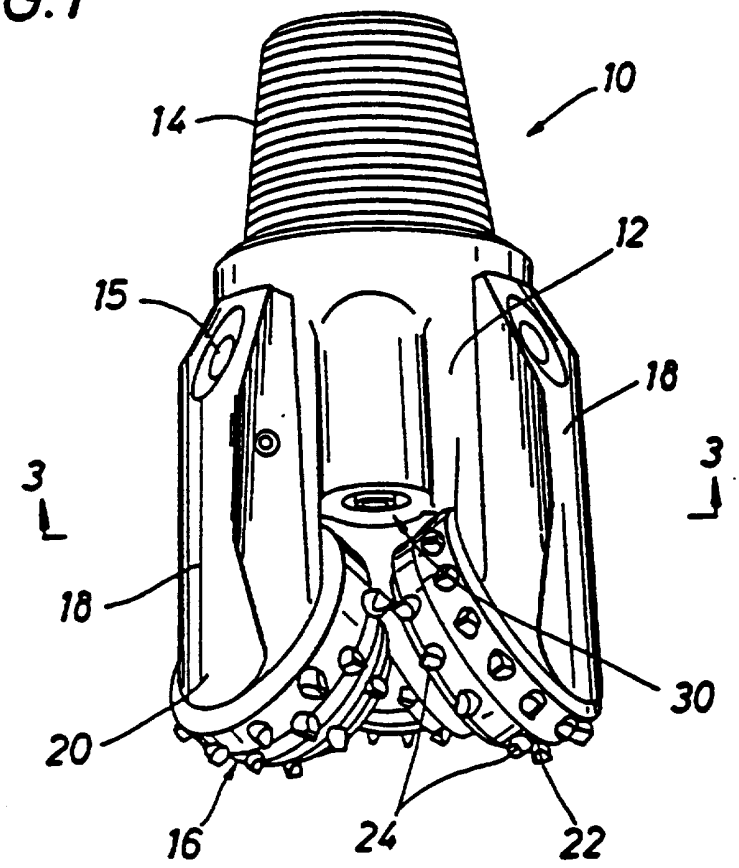
FIG. 1



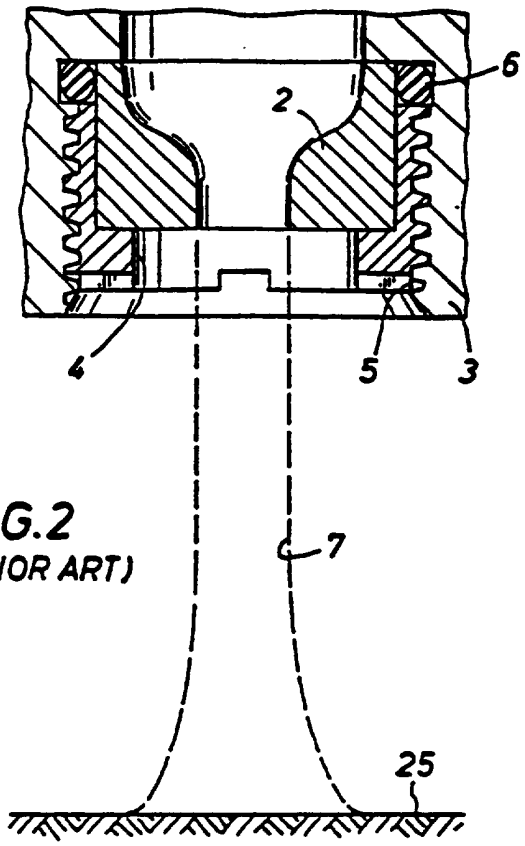
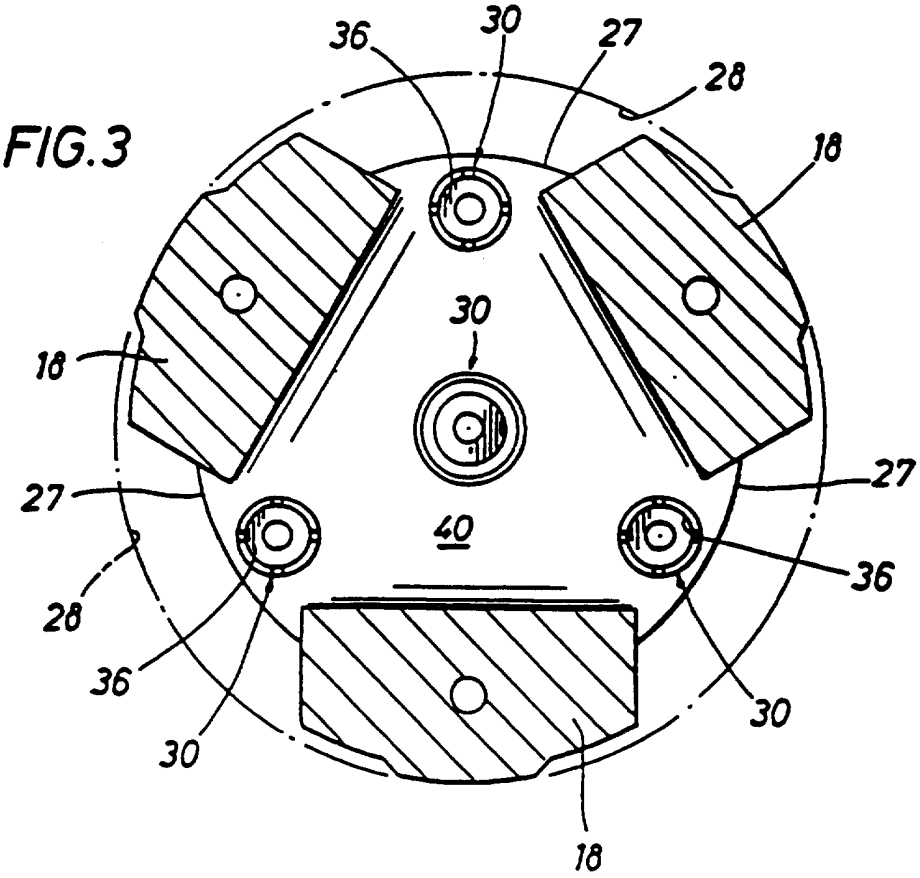


FIG.2
(PRIOR ART)

FIG.3



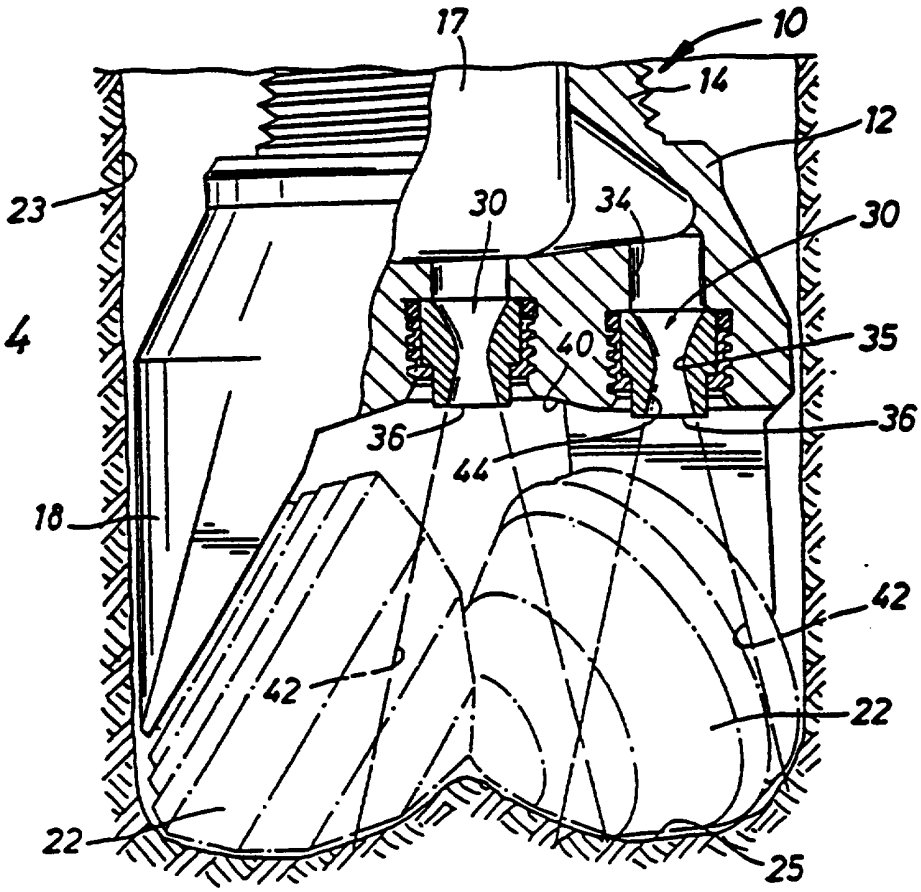

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FIG. 4

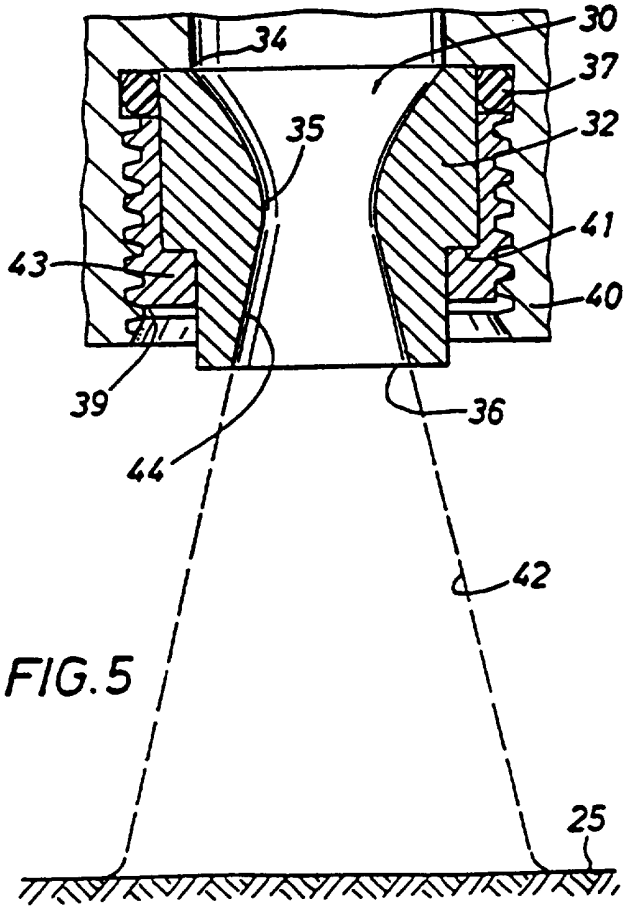
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FIG. 5

ROTARY CONE ROCK BIT

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

This invention relates to a rotary cone rock bit and particularly to the manipulation of the hydraulic energy exiting the fluid jet nozzles retained within the rock bit as the bit works in an earthen formation borehole.

More particularly, this invention relates to the use of one or more diffuser type nozzles in the outer periphery of a rotary cone rock bit body thereby providing improved cross flow by increasing bulk fluid motion across the borehole bottom. The use of diffuser nozzles also provides additional cone cleaning without eroding the cones as well as allowing for detritous removal past the diffuser jets positioned near the gage of the bit as the bit works in a borehole.

Diffuser type nozzles normally are used only in the center or dome portion of a rotary cone bit to remove debris that accumulates or "balls" in the space above the cones centrally of the bit when the bit is in operation. The use of diffuser jets on gage of rotary cone bits is especially effective in the softer, sticky types of earthen formations.

2. BACKGROUND

The use of nozzle jets in rotary cone rock bits to clean the cutting surfaces of the cones and to sweep the borehole clean of detritous as the rock bit is advanced in a borehole is well known in the petroleum industry.

Normally, a three cone rock bit consists of a center diffusion jet and three high flow/high velocity jets adjacent each 120 degree leg segment of the bit body and positioned near the peripheral edge or gage of the bit.

The center jet is a relatively low velocity diverging jet nozzle that widely diffuses fluid to keep the cutter cones clean and to remove debris that tends to ball up between the cones. The high velocity jets adjacent the gage of the bit direct fluid toward the borehole bottom to clear rock chips from the borehole so that the cutter cones may advance into the formation without grinding up old cuttings. Unfortunately, if the high velocity fluid of these jets passes to close to the cone surface, excessive cone erosion may occur resulting in lost inserts and damage to the cutter cones.

U.S. Patent Numbers' 4,369,849 and 4,516,642 attempt to direct fluid flow in such a manner as to move detritous from the borehole bottom. The '849 patent utilizes multiple nozzles at various angles with respect to the axis of the rock bit. The nozzles are also positioned around the dome area in a spiral pattern. The spiral nozzle configuration attempts to create a spiral flow path of fluid on the borehole bottom.

The '642 patent teaches directing a stream of fluid through a nozzle at the leading cutting edge of a rotary cutter cone to both clean the cutting elements of the cone and to move formation cuttings away from the advancing roller cone. In a multiple cone bit, each cone has its own fluid nozzle. The nozzle is canted or angled toward the leading edge of the rotary cone to clean the cone cutters extending from the surface of the cone. Unfortunately, the cuttings tend to circulate on bottom due to the nozzles being circumferentially spaced around the rock bit body.

U.S. Patent Numbers' 4,126,194; 4,187,921 and 4,189,014 are assigned to the same assignee as the present invention. These patents generally teach sweeping the bottom of a formation to remove debri therefrom.

The '194 patent teaches the use of two nozzles, one each in 120 degree leg segments, the third 120 degree leg

segment having a funnel type pickup tube axially aligned with the rock bit body. An inlet end of the pickup tube is positioned just above the borehole bottom. The object of the pickup tube is to sweep formation cuttings across the bottom and up the pickup tube. While this concept has considerable merit, the pickup tube lacks sufficient size to handle a large volume of cuttings,

The '921 patent utilizes opposed extended nozzles in a two rotary cone rock bit. Crossflow of hydraulic fluid is generated by cavitating one of the two opposed nozzles. The pressure differential between the pair of nozzles encourages crossflow thereby sweeping the borehole bottom during rock bit operation.

The '014 patent was also designed to enhance crossflow of drilling fluid over a borehole bottom. Two nozzles, one each in 120 degree leg segments are mounted in the bit body so that they extend slightly from a dome portion of the bit. Each nozzle is sealed on the gage side of the 120 degree leg segment to assure crossflow of fluid toward the remaining nozzleless 120 degree leg segment. The nozzleless segment is open to the borehole annulus for passage of the detritous up the annulus to the rig floor. A flow diverter is mounted in the center of the dome to decrease the dome area thereby increasing the flow velocity around the diverter and across the bit face. The diverter also serves to discourage the accumulation of formation cuttings that tend to accumulate or "ball up" in the center of the bit adjacent the dome.

If the detritous is not efficiently removed, the rock bit regrinds the cuttings endlessly resulting in shortening the life of the rock bit and a lessened bit penetration rate.

U.S. Patent Number 5,293,946 teaches and claims a divergent type fluid nozzle for one piece drag rock bits. The nozzles are designed to take advantage of the Coanda effect whereby the fluid adheres to the diverging nozzle

wall downstream of the throat section of the nozzle thereby minimizing turbulent flow exiting the nozzles. By opening up the nozzle exit, the patentee's teach that the nozzle is less apt to clog. Clogging of the fluid nozzles is a distinct possibility of drag type rock bits since the nozzle is necessarily positioned in the cutting face of the drag bit immediately adjacent the borehole bottom.

It is an object of this invention to provide a rotary cone rock bit enhanced cross flow of fluid over the bottom of the borehole.

SUMMARY OF THE INVENTION

According to this invention there is provided a rotary cone rock bit for use in an earthen formation, the rock bit being operable with drilling fluid, said rock bit comprising:

a rock bit body having a first end adapted to be connected to a drillstring and a second cutting end, said second cutting end comprising one or more rotary cutter cones rotatively retained on journal bearings extending from one or more rock bit leg segments connected to a dome portion formed by said bit body, said bit body further forming a plenum chamber therein for receiving said hydraulic drilling fluid, said chamber being in fluid communication with the first open pin end, and

one or more diffuser jets, the diffuser jets being formed by nozzle means, said nozzle means being connected to said dome portion of said bit body near an outer peripheral edge of the dome and adjacent a gage diameter formed by the bit, said nozzle means forming a first entrance end and a second exit end in communication with a fluid passage formed by the nozzle means, a restricted throat section intermediate said first and second ends of said nozzle means, said fluid passage below, in use, said

throat section being conically shaped and diverging from the lesser diameter restricted throat section to the larger diameter second exit end of the nozzle means, the conically shaped divergent throat section serving to diffuse the fluid without inducing turbulent flow as the fluid exits said second exit end thereby generating additional bulk fluid motion due to the diffused fluid exiting the nozzle having an increased surface area resulting in increased bottom hole cleaning and less cone erosion.

Preferably there are three approximately 120 degree leg segments, each leg segment forming for said nozzle means retention means nearest said outer peripheral edge of said dome portion of the bit.

In one embodiment there are three diffuser nozzle means, one in each leg segment of said rock bit, said diffusion nozzle means being positioned nearest the gage diameter formed by the rock bit.

In a further embodiment a fourth diffuser nozzle means is positioned in the center of the dome above the rotary cones, said center diffuser nozzle means serving to prevent borehole debris from balling in the center of the bit above the cones as the bit works in an earthen formation.

In another embodiment there are two diffuser nozzle means, one in each leg segment, the third leg segment being without a nozzle means, whereby a cross-flow of fluid moves from the two diffuser nozzle means toward the leg segment without a diffuser nozzle means resulting in a sweep of detritous material across the bottom of a borehole.

Advantageously a combined angle of a conically shaped nozzle means is 30 degrees or less.

According to a feature of this invention there is provided a rotary cone rock bit for use in an earthen formation, the rock bit being operated with drilling fluid:

a rock bit body having a first open pin end adapted to be connected to a drillstring and a second cutting end comprising three rotary cutter cones rotatively retained on journal bearings extending from rock bit leg segments connected to a dome portion formed by the bit body, each leg segment being about 120 degrees apart, the bit body further forming a plenum therein for receiving the drilling fluid, the chamber is in fluid communication with the first open pin end, and

a pair of diffuser type jets, the diffuser jets being formed by a nozzle body, said nozzle bodies are connected to the dome portion of the bit body, the nozzle bodies are connected to the dome portion of the bit body near an outer peripheral edge of the dome and between two of the three 120 degree bit leg segments connected to the dome, a third dome portion between the bit legs being without a diffuser jet, the nozzle body forming a first entrance end and a second exit end in fluid communication with a fluid passage formed by the nozzle body, intermediate the first and second ends of the nozzle body is a restricted throat section, the fluid passage below the throat section is conically shaped diverging from the smaller in diameter restricted throat section to a larger in diameter second exit end of the nozzle body, the conically shaped divergent nozzle portion serves to diffuse the fluid without inducing turbulent flow as the fluid exits the second nozzle exit end thereby generating additional bulk fluid motion since the diffused fluid existing the nozzle has an increased surface area resulting in increased bottom hole cleaning, the portion of the dome without a nozzle further creates a cross-flow of fluid that moves from the pair of diffusion jets, one each in two of the three 120 degree leg portions toward the 120 degree leg segment without a diffusion jet resulting in a sweep of detritous material across the bottom of the borehole.

The present invention primarily uses diffusion type

nozzles around the outer peripheral edge of the rock bit to clean the cones and to enhance cross flow of fluid across the hole bottom to increase the rate of penetration on the bit in a borehole.

One of the important features of the present invention is the creation of a wider field of fluid without turbulence created by the larger conical cone of exiting fluid.

In this invention the inherent benefits of diffuser nozzles are used to create an enhanced cross flow of fluid across the hole bottom and to enhance cone cleaning by locating the diffuser nozzles in the outer periphery of the bit body to increase the bulk flow of fluid through the bit hence improving the bit rate of penetration.

As fluid leaves a diffuser nozzle, it continues to diffuse outboard creating a larger fluidic surface area to entrain fluid. This generates greater bulk fluid motion.

A diffused spray will better clean cones by moving the flowing fluid closer to the cones. Since the diffused fluid travels at a slower velocity, cone erosion is less likely, especially due to splashback of fluid from the borehole bottom as the bit works in a borehole.

Since the diffused spray will impinge over a larger area of the hole bottom, more of the hole bottom will be cleaned by jetted fluid flow.

The conically shaped nozzle serves to diffuse the fluid as the fluid exits the nozzle thereby generating additional bulk fluid motion since the diffused fluid exiting the nozzle has an increased surface area resulting in increased bottom hole cleaning and less cone erosion.

An advantage then of the present invention over the prior art is the use of diffusion nozzle jets in place of high velocity, high flow nozzles located around the outer periphery of a bit body nearest the gage diameter formed

by the bit.

Another advantage of the present invention over the prior art is improved bottom hole cleaning through the use of diffusion type hydraulic nozzles instead of high flow, high pressure nozzles commonly used around the peripheral edge of state of the art bits.

Still another advantage of the present invention over the prior art is improved cleaning of the rotary cones without erosive damage to the cones through the use of diffusion nozzles in place of high pressure, high flow nozzles utilized in the outer peripheral edge of state of the art rotary cone rock bits.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described by way of example with reference to the accompanying drawings in which:-

FIGURE 1 is a perspective view of a typical rotary cone rock bit used in this invention that utilizes hydraulic fluid to cool the bit and to remove the debris from the bottom of a borehole when drilling in an earthen formation;

FIGURE 2 is a cross-section of a prior art high flow, high pressure nozzle jet illustrating a high flow, narrowly confined stream of hydraulic fluid exiting the nozzle;

FIGURE 3 is a view taken through 3-3 of Figure 1 illustrating the location of diffusion nozzle jets relative to the outer peripheral edge of the dome portion of the bit body;

FIGURE 4 is a partial cross-section of the bit body depicting one of the diffusion nozzle jets used in this invention mounted in the dome portion of the bit nearest a gage diameter of the bit in communication with the plenum chamber formed by the bit body, a center diffusion

jet being mounted in the center of the dome, and

FIGURE 5 is a cross-section of the preferred embodiment of the invention illustrating a diffusion type nozzle jet with a conically shaped nozzle portion downstream of a restricted throat portion of the nozzle passage formed by the nozzle body.

In the Figures like reference numerals denote like parts.

DESCRIPTION OF THE PREFERRED EMBODIMENTS AND BEST MODE FOR CARRYING OUT THE INVENTION

The rotary cone rock bit of Figure 1, generally designated as 10, consists of a rock bit body 12, threaded pin end 14 and a cutting end generally designated as 16. The cutting end of the bit 16 comprises cutter cones 22 that are rotatably attached to a bearing journal extending from the bottom or shirttail portion 20 of leg 18. Each of the cones, for example, contain a multiplicity of cutter inserts 24 secured to cones 22. The rock bit, however, may have milled teeth rotary cones without departing from the scope of the invention.

The prior art illustrated in Figure 2 depicts a standard nozzle body 2 seated within a nozzle opening 5 formed in a dome portion 3 of a rotary cone rock bit. The nozzle body 2 is typically secured within a nozzle opening 5 by a threaded nozzle retainer 4. An O-Ring 6 prevents leakage between the interior of the rock bit body and the threaded retainer 4. A high flow/high velocity stream of fluid ["mud"] 7 exits the nozzle and impacts the borehole bottom 25. If the high velocity stream of mud 7 should strike the rotary cones, cone erosion and lose of inserts retained in the cone surface is a distinct possibility thus cutting short the life of the rock bit.

With reference now to Figure 3, the preferred

diffusion nozzle jets generally designated as 30 are located in the dome surface 40. For example, three of the diffusion nozzles are located adjacent the peripheral edge 27 of the dome about 120 degrees apart. It is preferable to position the diffusion nozzles as close to the gage 28 of the bit to take full advantage of the bottom hole cleaning capacity of the diffused stream of fluid exiting the diffusion nozzles 30.

A diffusion center jet nozzle 30 is positioned in the middle of the dome to inhibit the build up of debri above the cones 22 as the bit works in a borehole. The diffused stream of fluid from the center jet nozzle has a lower velocity and thus is less prone to damaging the cones 22 through erosion [see Fig. 4].

Referring now to Figures 4 and 5, Figure 4 illustrates a rotary cone rock bit 10 working in a borehole 23. A diffusion nozzle 30 is located in the dome 40 nearest the dome periphery 27. As heretofore stated, a diffusion nozzle 30 is located in each 120 degree leg segment 18 of the bit body 12 [see Fig.3].

A center diffusion jet nozzle 30 is additionally located in the middle of the dome to prevent bit balling above the cones.

With specific reference to Figure 5, the diffusion jet 30 seats within the dome 40 and is secured within the threaded inlet 39 formed in dome 40 by threaded retainer ring 38. A flange 43 of retainer ring 38 engages shoulder 41 of the nozzle body 32 and O-Ring 37 positioned adjacent nozzle inlet 34 inhibits leakage of hydraulic fluid past the retainer 38 when the retainer ring is tightened within the threaded inlet 39. The nozzle body 32 forms an inlet 34 and an exit 36. Intermediate ends 34 and 36 is a reduced in diameter throat section 35.

A conical exit nozzle portion 44 is preferably formed below the throat section 35. The diverging walls of the cone creates a conical flow of fluid exiting

nozzle exit 36 that, as the fluid leaves the diffuser nozzle, it continues to diffuse outboard 42 toward borehole bottom 25 thereby creating a larger surface area to entrain fluid. The combined angle of the diverging wall is about 30 degrees or less or about 15 degrees from a center line of the nozzle. A larger angle would result in separation of the fluid from the diverged wall causing turbulent flow of the fluid. The conical exit nozzle generates greater bulk fluid motion as seen in Figure 5 resulting in an increased bulk fluid motion as heretofore stated.

A diffused spray of fluid will better clean cones by moving the flowing fluid closer to the cones made possible by the wider field of fluid created by the larger conical cone of exiting fluid. Since the diffused fluid travels at a lower velocity, cone erosion is less likely, especially due to splashback of fluid from the borehole bottom 25. Moreover, since the diffused spray 42 exiting nozzle exit 36 will impinge over a larger area of the borehole bottom 25, [as seen by the overlapping cones 42 in Fig. 4], more of the hole bottom 25 will be cleaned of detritous by the jetted fluid flow 42.

It would be obvious to use less than three diffused nozzles in the outer peripheral gage area of the dome 40 without departing from the scope of this invention. One of the 120 degree leg segments could, for example, be sealed off resulting in a cross-flow of fluid from the remaining two diffused nozzles 30 toward the nozzleless portion of the dome to more effectively sweep the borehole bottom of detritous.

Moreover, it would be obvious to utilize one or more conventional or noncoventional prior art nozzles such as a standard nozzle 2 (Figure 2) in combination with one or more of the preferred divergent nozzles 30 in a rotary cone rock bit to achieve a cross-flow of fluid on the borehole bottom without departing from the teachings of this invention.

It would also be obvious that the diffused flow pattern could be generated by diffuser shapes other than the preferred conical shape taught by this invention.

It will of course be realized that various modifications can be made in the design and operation of the present invention without departing from the spirit thereof. Thus while the principal preferred construction and mode of operation of the invention have been explained in what is now considered to represent its best embodiments which have been illustrated and described, it should be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically illustrated and described.

CLAIMS:

1. A rotary cone rock bit for use in an earthen formation, the rock bit being operable with drilling fluid, said rock bit comprising:

a rock bit body having a first end adapted to be connected to a drillstring and a second cutting end, said second cutting end comprising one or more rotary cutter cones rotatively retained on journal bearings extending from one or more rock bit leg segments connected to a dome portion formed by said bit body, said bit body further forming a plenum chamber therein for receiving said hydraulic drilling fluid, said chamber being in fluid communication with the first open pin end, and

one or more diffuser jets, the diffuser jets being formed by nozzle means, said nozzle means being connected to said dome portion of said bit body near an outer peripheral edge of the dome and adjacent a gage diameter formed by the bit, said nozzle means forming a first entrance end and a second exit end in communication with a fluid passage formed by the nozzle means, a restricted throat section intermediate said first and second ends of said nozzle means, said fluid passage below, in use, said throat section being conically shaped and diverging from the lesser diameter restricted throat section to the larger diameter second exit end of the nozzle means, the conically shaped divergent throat section serving to diffuse the fluid without inducing turbulent flow as the fluid exits said second exit end thereby generating additional bulk fluid motion due to the diffused fluid exiting the nozzle having an increased surface area resulting in increased bottom hole cleaning and less cone erosion.

2. A rotary cone rock bit as claimed in claim 1 wherein there are three approximately 120 degree leg segments, each leg segment forming for said nozzle means retention

means nearest said outer peripheral edge of said dome portion of the bit.

3. A rotary cone rock bit as claimed in claim 2 wherein there are three diffuser nozzle means, one in each leg segment of said rock bit, said diffusion nozzle means being positioned nearest the gage diameter formed by the rock bit.

4. A rotary cone rock bit as claimed in claim 3 wherein a fourth diffuser nozzle means is positioned in the center of the dome above the rotary cones, said center diffuser nozzle means serving to prevent borehole debris from balling in the center of the bit above the cones as the bit works in an earthen formation.

5. A rotary cone rock bit as claimed in any of claims 1 or 2 wherein there are two diffuser nozzle means, one in each leg segment, the third leg segment being without a nozzle means, whereby a cross-flow of fluid moves from the two diffuser nozzle means toward the leg segment without a diffuser nozzle means resulting in a sweep of detritous material across the bottom of a borehole.

6. A rotary cone rock bit for use in an earthen formation, the rock bit being operated with drilling fluid:

a rock bit body having a first open pin end adapted to be connected to a drillstring and a second cutting end comprising three rotary cutter cones rotatively retained on journal bearings extending from rock bit leg segments connected to a dome portion formed by the bit body, each leg segment being about 120 degrees apart, the bit body further forming a plenum therein for receiving the drilling fluid, the chamber is in fluid communication with the first open pin end, and

a pair of diffuser type jets, the diffuser jets

being formed by a nozzle body, said nozzle bodies are connected to the dome portion of the bit body, the nozzle bodies are connected to the dome portion of the bit body near an outer peripheral edge of the dome and between two of the three 120 degree bit leg segments connected to the dome, a third dome portion between the bit legs being without a diffuser jet, the nozzle body forming a first entrance end and a second exit end in fluid communication with a fluid passage formed by the nozzle body, intermediate the first and second ends of the nozzle body is a restricted throat section, the fluid passage below the throat section is conically shaped diverging from the smaller in diameter restricted throat section to a larger in diameter second exit end of the nozzle body, the conically shaped divergent nozzle portion serves to diffuse the fluid without inducing turbulent flow as the fluid exits the second nozzle exit end thereby generating additional bulk fluid motion since the diffused fluid existing the nozzle has an increased surface area resulting in increased bottom hole cleaning, the portion of the dome without a nozzle further creates a cross-flow of fluid that moves from the pair of diffusion jets, one each in two of the three 120 degree leg portions toward the 120 degree leg segment without a diffusion jet resulting in a sweep of detritous material across the bottom of the borehole.

7. A rotary cone rock bit as claimed in claim 1 wherein a combined angle of a conically shaped nozzle means is 30 degrees or less.

8. A rotary cone rock bit substantially as herein described with reference to and as shown in Figs. 1, 3-5 of the accompanying drawings.

The Patent Office

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Application No: GB 9609754.8 **Examiner:** David Harrison
Claims searched: 1 to 8 **Date of search:** 10 July 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): E1F (FGD)

Int Cl (Ed.6): E21B

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	US 5293946	(Besson et al)	1
A	US 4687067	(Smith et al)	1
A	US 4687066	(Evans)	6

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.