

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
29 November 2007 (29.11.2007)

PCT

(10) International Publication Number
WO 2007/136568 A2

(51) International Patent Classification:

E21B 10/02 (2006.01) *E21B 10/60* (2006.01)
E21B 25/00 (2006.01)

(21) International Application Number:

PCT/US2007/011355

(22) International Filing Date: 10 May 2007 (10.05.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

60/800,620 15 May 2006 (15.05.2006) US
11/746,931 10 May 2007 (10.05.2007) US

(71) Applicant (for all designated States except US): **BAKER HUGHES INCORPORATED** [US/US]; 2929 Allen Parkway, Suite 2100, Houston, TX 77019-2118 (US).

(72) Inventors: **WILSON, Bob, T.**; P. O. Box 567, Dubai (AE). **REGENER, Thorsten**; Birkenweg 9, Wienhausen, Niedersachsen, 29342 (DE).

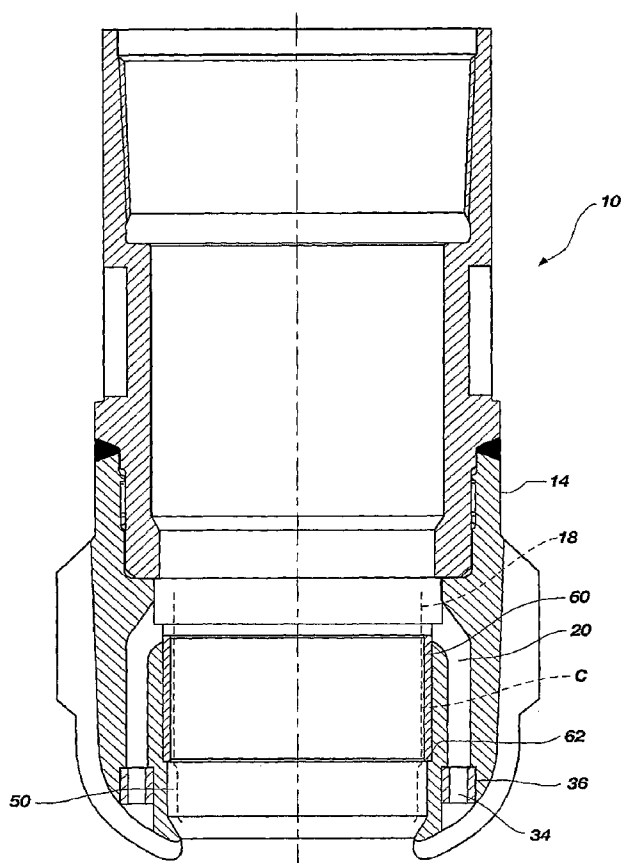
(74) Agents: **RIDDLE, Albert, J.** et al.; Baker Hughes Incorporated, 2929 Allen Parkway, Suite 2100, Houston, TX 77019-2118 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),

[Continued on next page]

(54) Title: CORE DRILL ASSEMBLY WITH ADJUSTABLE TOTAL FLOW AREA AND RESTRICTED FLOW BETWEEN OUTER AND INNER BARREL ASSEMBLIES



(57) Abstract: A core drill assembly with replaceable cutting fluid nozzles permitting effective total flow area adjustment (TFA), substantial optimization of hydraulic force at the cutting face to improve rate of penetration (ROP) and core quality. At least one seal assembly to restrict drilling fluid flow while permitting mutual rotation between the core head ID and the lower shoe is disposed in an annulus defined therebetween.

WO 2007/136568 A2



European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Published:

- *without international search report and to be republished upon receipt of that report*

**CORE DRILL ASSEMBLY WITH ADJUSTABLE TOTAL FLOW AREA AND
RESTRICTED FLOW BETWEEN OUTER AND INNER BARREL
ASSEMBLIES**

5 **INVENTORS: WILSON, Bob T. and REGENER, Thorsten**

TECHNICAL FIELD

Embodiments of the present invention are related to a core drill assembly with
10 adjustable drill fluid total flow area and, more particularly, to a core drill assembly
which includes replaceable cutting fluid nozzles and a seal assembly disposed between
adjacent portions of the outer barrel assembly and the inner barrel assembly, as well as
to methods of coring.

BACKGROUND

15 Current core head designs use a fixed total flow area (TFA) to circulate drilling
fluid through the core head, also known as a core bit, during down-hole coring
operations. The TFA is a calculated discharge area for the drilling fluid which may
include an annulus ID gauge fluid course between the core head ID and the exterior of
the lower shoe, carried by the inner barrel assembly, or core head face discharge ports,
20 or a combination of the two. Drilling fluid is circulated through the ID fluid courses
and the face discharge ports to cool and clean cutting structure carried on the face of the
core head, and to remove cuttings generated when the cutting head penetrates the
formation being cored. The hydraulic force, or the ability of the drilling fluid to
removing material cuttings from the cutting head face, is measured in hydraulic
25 horsepower/ in² (HSI) and is an indicator of drilling fluid cleaning efficiency. If the
hydraulic force is too low, there will be poor cleaning of the cutting structure and
cuttings will interfere with the rate of penetration (ROP) in forming the bore hole. If
the hydraulic force is too high, there may be erosion of the bore hole, which can result
in a stuck drill string, and the drilling fluid may contaminate the core sample. By using
30 HSI and ROP measurements, the optimum amount of hydraulic force can be designed
into a core drill assembly.

FIG. 1 is a cross-section of a conventional core drill assembly 10, with a non-
adjustable TFA or drilling fluid flow area defined by the areas of the annulus 50 and the
discharge ports 30. The annulus 50 is the gap between the ID of core head 14 and the
35 outside of the lower shoe 18. With this arrangement, drilling fluid is pumped down the

drill string, to core drill assembly 10, where a portion of the drilling fluid will travel through the annulus 50 and exit the core drill assembly 10 proximate the leading edge of the lower shoe 18, while the remaining drilling fluid enters the fluid course 20 within in core head 14, and exits the discharge port 30 located on the face 16 of core head 14, as respectively shown by the arrows in FIG. 1. The drilling fluid is used to cool the cutters 60 and flush cuttings away from the core head face 16. However, since the TFA is non-adjustable, the operator cannot optimize the amount of drilling fluid at the drill face 16 and the HSI.

With the non-adjustable TFA of current core head designs, the only variable is the circulation rate of the drilling fluid, and therefore, the HSI cannot be optimized. Also, in current core heads there is always some drilling fluid flow through the annular space between the core head ID and the lower shoe. In core heads using ID fluid courses only, all of the flow travels through the annulus whereas, when core head face discharge ports are used in combination with the annulus, it is difficult to determine amount of drilling fluid "split" between the discharge ports and the annulus. The difficulty arises because the actual annulus gap spacing between the core head ID and the lower shoe is not known when the core head is down hole. The annulus gap is nominally 0.95 cm to 1.27 cm ($\frac{3}{8}$ " to $\frac{1}{2}$ "); however, when using an aluminum or fiberglass inner tube, in the inner barrel assembly, gaps up to about 14 cm ($5\frac{1}{2}$ ") may be required in order to compensate for the different rates of thermal expansion attributed to the materials of the inner tube and the core head. Under bottom-hole temperature, the gap may decrease to the estimated desirable gap of 0.95 mm to 1.27 cm ($\frac{3}{8}$ " to $\frac{1}{2}$ "), but uncertainty about the actual and estimated bottom-hole temperature, can result in a significant error in spacing adjustment. As the area of the annulus gap is added directly into the TFA calculation, the uncertainty of the gap size makes accurately calculating TFA difficult. The split of flow between the annulus between the OD of the inner tube shoe and the ID of the core head, and the face discharge ports is dependent upon their relative TFA. Depending upon actual spacing down hole, the annular TFA could be higher than the TFA of the face discharge ports, with the result that most of the flow of drilling fluid will pass through the ID annulus. This significantly reduces the effectiveness of the face discharge ports, and reduces further the HSI delivered to the cutting structure of the core head. Adjusting the TFA of the face discharge ports in this case would not increase HSI, since the bypass flow would

simple be increased through the ID annulus. To increase HSI, the bypass flow through the ID annulus must be sealed off, or severely restricted, to divert as much of the flow as possible to the face discharge ports, or nozzles.

For a conventional drill bit with replaceable nozzles, the TFA can be optimized
5 by utilizing different diameter nozzles in the discharge ports. However, in a conventional core drill assembly, since at least some of the drilling fluid flow travels through the annulus, a change of discharge port size will change the resistance at the nozzles and will proportionally change the amount of drilling fluid bypassing through the annulus. This problem is highlighted when looking at the performance of the drill
10 bit versus a core drill. A drill bit will normally operate in the range of 4-8 HSI, whereas 21.6 cm x 10.16 cm (8 1/2" x 4") core drill may operate as low as 0.2 HSI.

In view of the shortcomings in the art, it would be advantageous to provide a core drill with adjustable TFA, by fitting the core head with replaceable cutting fluid nozzles and sealing off the annulus between the core head ID and the lower shoe. This
15 will allow an operator to apply the same drilling optimization concepts to coring as used with conventional drilling, and allow the HSI to be improved over conventional core head designs, with corresponding improvements in coring performance, ROP and core quality.

20 DISCLOSURE OF INVENTION

Embodiments of the invention include replaceable nozzles fitted in at least some of the drilling fluid outlet ports, proximate the face of the core head. The nozzle design will compensate for the smaller surface area of the typical core drill face and new nozzle locations and jet directions are contemplated to take advantage of the improved
25 HSI at the cutting face, including directing nozzles towards interior cutters of the core head in order to clear cuttings and provide cooling.

In one embodiment of the present invention, the annulus between the cutting head and the lower shoe is substantially sealed with a seal structure, which may be broadly characterized as a seal assembly or a seal element, without substantial
30 rotational interference between the core head and the lower shoe, which would cause the lower shoe and inner tube to turn with the outer barrel assembly and core head.

One embodiment includes one or more grooves formed into the ID of the core head to accommodate an annular seal similar to an O-ring in each of the grooves. The

design of the O-ring or other annular seal allows some drilling fluid flow to bypass under reduced pressure, but under normal operating circumstances the O-ring or other annular seal seals substantially completely.

In a second embodiment of the present invention, the annulus between the core head and the lower shoe is substantially sealed using split rings made from a material such as nylon or Teflon®. This embodiment includes one or more grooves formed in the ID of the core head where split rings of the appropriate size are installed to seal the annulus. The seals will fit somewhat loosely in the grooves and may rotate during coring operations, but will provide a sufficient seal to enable effective TFA adjustments by installing different sizes of drilling fluid nozzles. The loose fit will reduce friction between the core head ID and the lower shoe, to eliminate any tendency for the lower shoe and inner tube to rotate.

Other embodiments of the present invention employ one or more of a wiper seal, a chevron seal, a packer cup or a restrictor sleeve disposed between the core head and the lower shoe to substantially restrict fluid flow therebetween while permitting rotational movement of the core head about the lower shoe.

Embodiments of the present invention also include methods of using a core drill assembly.

BRIEF DESCRIPTION OF DRAWINGS

The foregoing and other advantages of the invention will become apparent upon reading the following detailed description and upon reference to the drawings in which:

FIG. 1 is a cross-section of a conventional core drill assembly with a non-adjustable TFA defined by the area of the annulus between the core head and the lower shoe, and the area of the drilling fluid ports;

FIG. 2 is a cross-section of a core drill assembly with a seal structure between the core head and the lower shoe and replaceable drilling fluid nozzles;

FIG. 3 is a partial cross-section of a core drill assembly including a O-ring or wiper seal type seal assembly;

FIG. 4 is a partial cross-section of a core drill assembly including a split-ring type seal assembly;

FIG. 5 is a partial cross-section of a core drill assembly including a labyrinth seal assembly; and

FIG. 6 is a partial cross-section of a core drill assembly including a restrictor sleeve.

MODES FOR CARRYING OUT THE INVENTION

FIG. 2 schematically depicts a core drill assembly 10 of the present invention including replaceable discharge nozzles 36 at the discharge ends of fluid courses 20, and at least one seal assembly 40 disposed between the core head 14 and the lower shoe 18. These features allow the operator to change the TFA of the core drill assembly 10 and optimize the HSI. The operator can select nozzles 36 having a discharge opening 34 of an appropriate diameter to adjust TFA. Thus, if a volume of drilling fluid is pumped under pressure, at a substantially constant flow rate, down the drill string, seal assembly 40 will divert substantially all of the drilling fluid volume away from the annulus 50 and into the fluid courses 20 where the drilling fluid will exit through discharge opening 34 of replaceable nozzles 36. The diameters of discharge openings 34 will affect both the rate of discharge and the velocity of the escaping drilling fluid. Under optimized conditions, as provided by the present invention, the drilling fluid, emanating from the discharge openings 34, will effectively clear cuttings away from the core head face 16 and properly cool cutters 60. The optimum diameter discharge openings 34 for a specific material or formation, and core head or core size, can be determined or predicted by the use of historical data, including ROP measurements. As shown at the left-hand side of FIG. 2, the seal assembly 40 may be partially received in a groove in ID of the core head 14 or, as shown at the right-hand side of FIG. 2, the seal assembly 40 may be partially received in a groove in the exterior of the lower shoe 18. As core head 14 rotates about lower shoe 18 during a coring operation, fluid flow therebetween will be substantially restricted by seal assembly 40, as indicated by the smaller size of the arrows below annulus 50 in comparison to those in fluid courses 20.

FIGS. 3 and 4, are partial cross-section views of core drill assembly 10 provided, to show additional detail of several embodiments of the at least one seal assembly 40. The at least one seal assembly 40 is positioned in the annulus 50, or the gap defined between the ID of core head 14 and the outside of the lower shoe 18. The seals 42 and 44 are installed in grooves 46 formed in the ID of core head 14. The seals 44 shown in FIG. 3 may comprise an O-ring or other continuous ring type that may have a round or oval cross-section, or may include lips which function as

“wipers,” as shown. The material of seals 44 may include, but is not limited to, rubber, neoprene, or polyethylene or a combination thereof. The seals 42 shown in FIG. 4 are of a split ring design which rides loosely in the grooves 46. Examples of suitable materials for the split ring seals 42 are nylon and Teflon® polymers. The at least one seal assembly 40 will substantially restrict the flow of the drilling fluid pumped down the drill string, forcing the drilling fluid to bypass the annulus 50 and into the fluid courses 20, traveling in the direction of flow arrows 26.

FIG. 5 is a partial cross-section view of a core drill assembly 10 including a labyrinth seal assembly 48 having a plurality of radially projecting, axially spaced annular elements separated by slots 56. The labyrinth seal assembly 48 is formed into the structure of one of the core head 14 ID or the exterior surface of the lower shoe 18. However, a labyrinth seal 48 with mating, interdigitated elements or components E as shown in broken lines can be formed with the cooperating parts disposed on both the core head 14 ID and the lower shoe 18. The total number of labyrinth slots 56 is not specified, and will vary depending on the expected pressure differential between the pumped drilling fluid and drill work face. The labyrinth seal assembly 48 must have sufficient length and number of slots 56 to effectively seal annulus 50. With annulus 50 sealed, the drilling fluid will enter fluid courses 20, flowing in the direction indicated by flow arrows 26.

It is also contemplated that the seals may be carried on the exterior of the lower shoe 18 instead of on core head 14, or may be carried on both components. It is also contemplated that a seal comprising an upwardly facing packer cup with a frustoconical elastomeric skirt may be utilized in addition to, or in lieu of, other seal configurations. Chevron type seals, as well as metallic or elastomeric seal back-up components, may also be employed.

FIG. 6 depicts yet another embodiment of the present invention, wherein a seal element in the form of restrictor sleeve 60 is disposed on an annular shoulder 62 machined or otherwise formed on the ID of the core head 14, and retained therein through the use of an appropriate bonding agent, such as BAKERLOK® compound, available from various operating units of Baker Hughes Incorporated, assignee of the present invention. As with the previous embodiments, discharge openings 34 of replaceable nozzles 36 may be selected for optimum TFA. A conventional lower core shoe 18 is run inside of core head 14, and extends longitudinally therethrough. The

outer surface (shown in broken lines for clarity) of lower shoe 18 is in close proximity to the ID of restrictor sleeve 60, so that a very small clearance radial clearance C, for example about 1 mm, is achieved. This small, annular clearance C between core shoe 18 and restrictor sleeve 60, while permitting rotation of core shoe 18 and restrictor sleeve 60 about lower shoe 18, will substantially restrict the flow of the drilling fluid pumped down the drill string, forcing the drilling fluid to bypass the annulus 50 and into the fluid courses 20 to exit through discharge openings of replaceable nozzles 36.

While the present invention has been depicted and described with reference to certain embodiments, the invention is not so limited. Additions and modifications to, and deletions from, the described embodiments will be readily apparent to those of ordinary skill in the art. The present invention is, thus, limited only by the claims which follow, and equivalents thereof.

CLAIMS

What is claimed is:

1. A core drill assembly comprising:
 - 5 a core head including an inside diameter, a face, and at least one fluid course having an outlet on the face;
 - a lower shoe;
 - at least one replaceable nozzle disposed in the at least one fluid course proximate the outlet; and
 - 10 at least one seal structure, configured to permit rotation between the core head and lower shoe assembly, disposed between the core head inside diameter and an exterior surface of the lower shoe.
2. The assembly of claim 1, wherein the at least one replaceable nozzle is
15 replaceable with another replaceable nozzle having a different inner diameter.
3. The assembly of claim 1, wherein the at least one seal structure comprises a seal assembly and includes at least one groove formed on at least one of the inside diameter of the core head and the exterior surface of the lower shoe.
20
4. The assembly of claim 3, wherein the at least one seal assembly includes at least one seal element carried in the at least one groove.
5. The assembly of claim 4, wherein the at least one seal element is at least
25 one of an o-ring seal, a wiper seal, a split-ring seal, a chevron seal or a packer cup.
6. The assembly of claim 4, wherein the at least one seal element is made of at least one of a nylon, a Teflon®, a polyethylene, a rubber or a neoprene material.
- 30 7. The assembly of claim 1, wherein the at least one seal structure comprises a labyrinth seal.

8. The assembly of claim 1, wherein the at least one seal structure comprises a restrictor sleeve disposed within the core head laterally adjacent an exterior surface of the lower shoe.

5 9. The assembly of claim 8, wherein the restrictor sleeve rests on an annular shoulder on the ID of the core head.

10 10. The assembly of claim 8, wherein an ID of the restrictor sleeve and the laterally adjacent exterior surface of the lower shoe are mutually spaced by about 1 mm.

11. A method for substantially controlling the total flow area (TFA) of a core drill assembly comprising:
providing a core head including at least one fluid course having an outlet on the face
15 thereof;
installing a replaceable nozzle having a selected inner diameter in the fluid course proximate the outlet;
disposing a lower shoe at least partially within the core head; and
rotating the core head about the lower shoe while substantially preventing a flow of
20 drilling fluid between the core head and the lower shoe and directing flow through the at least one replaceable nozzle.

12. The method of claim 11, further including replacing the at least one replaceable nozzle with another replaceable nozzle having a different inner diameter.

25

13. The method of claim 13, further comprising providing an absolute fluid seal between the core head and the lower shoe.

+

1/5

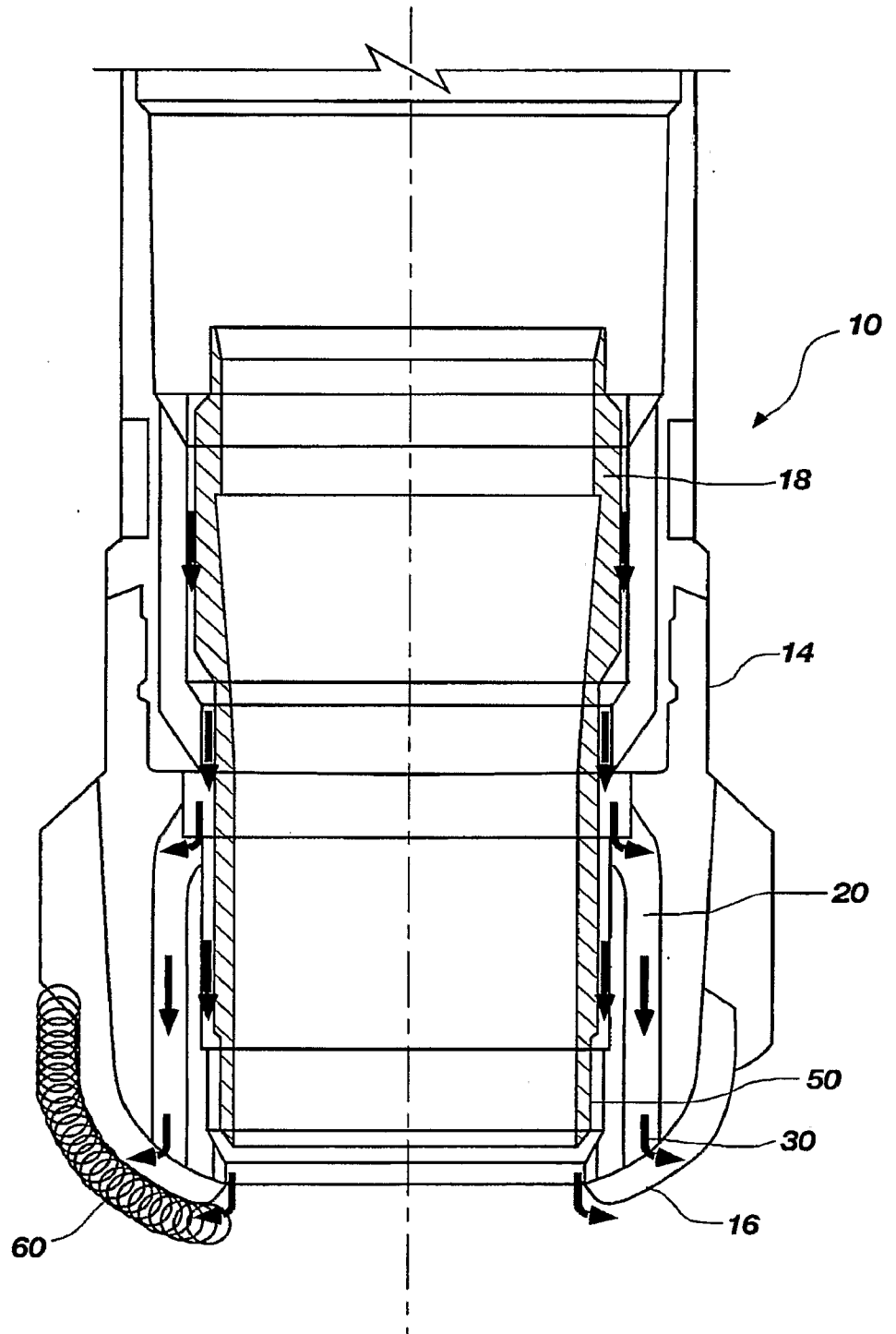


FIG. 1
(PRIOR ART)

+

2/5

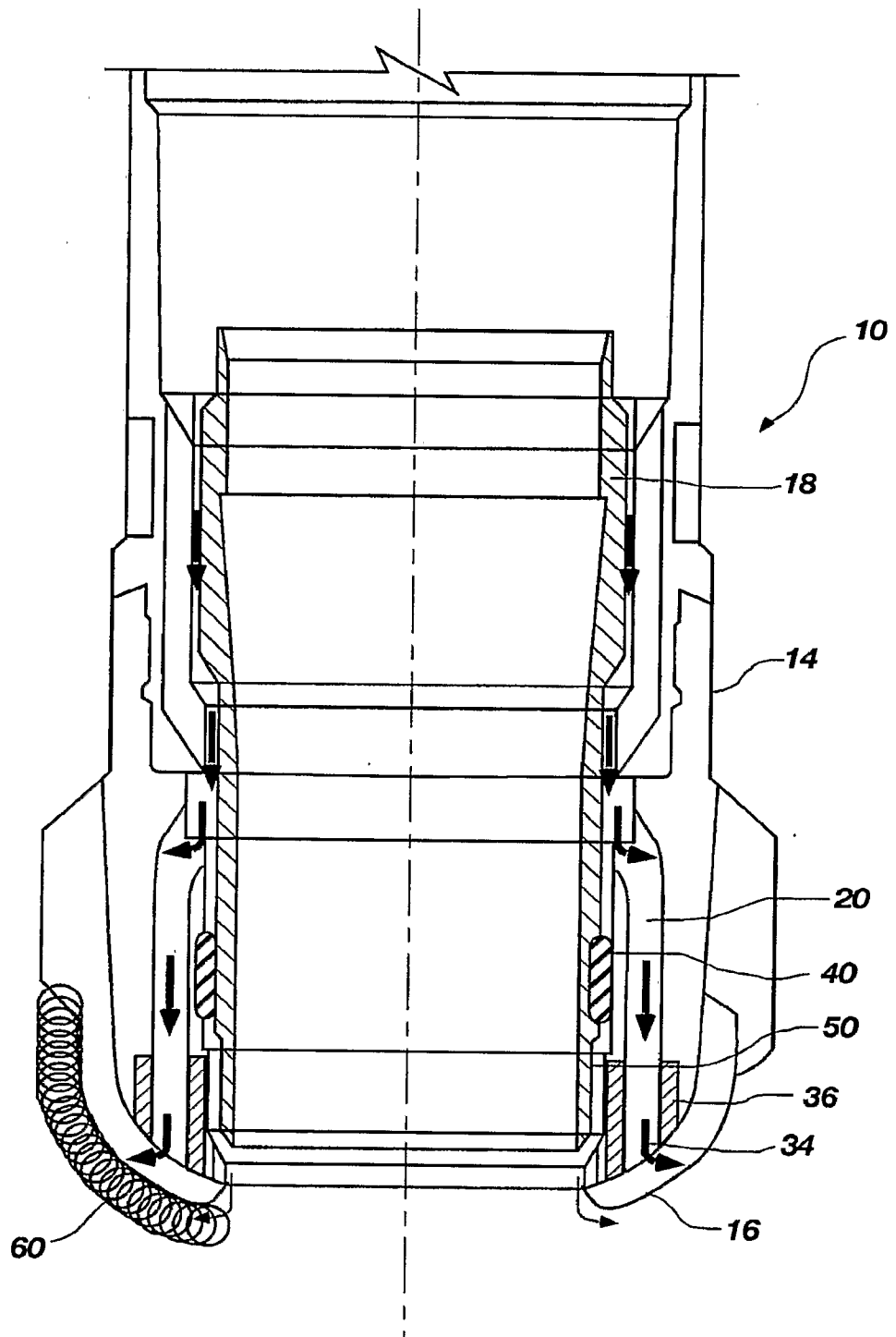


FIG. 2

+

3/5

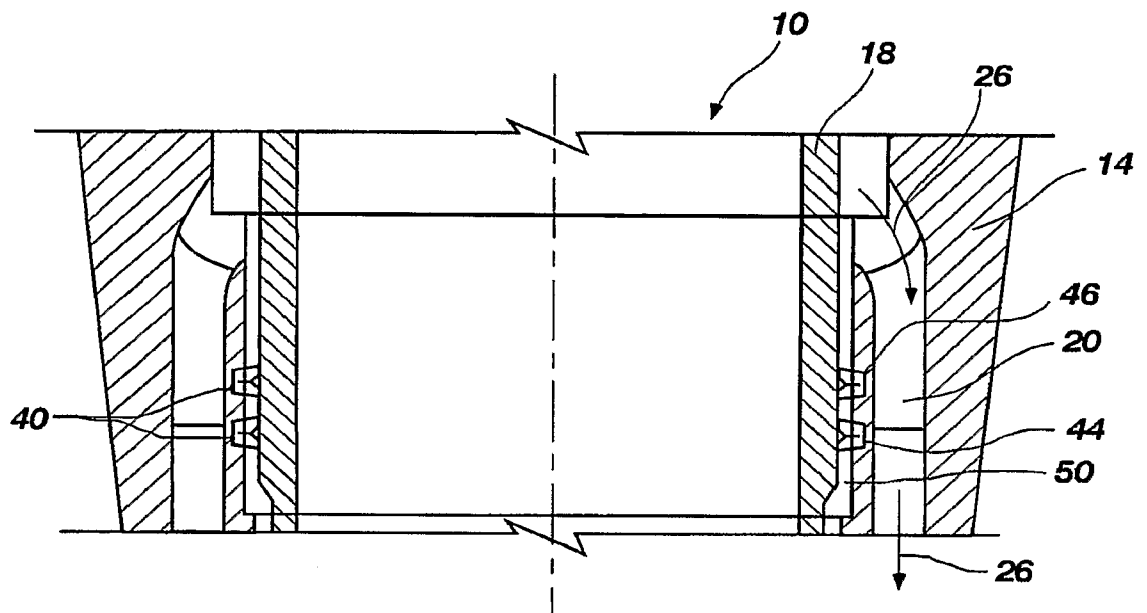
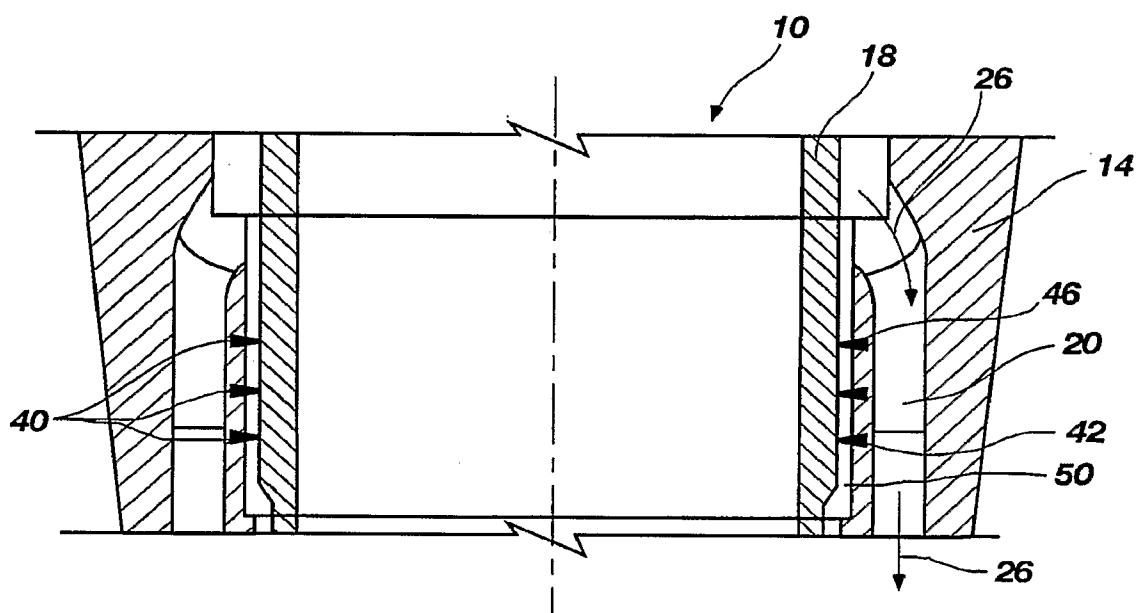


FIG. 3

**FIG. 4**

+

4/5

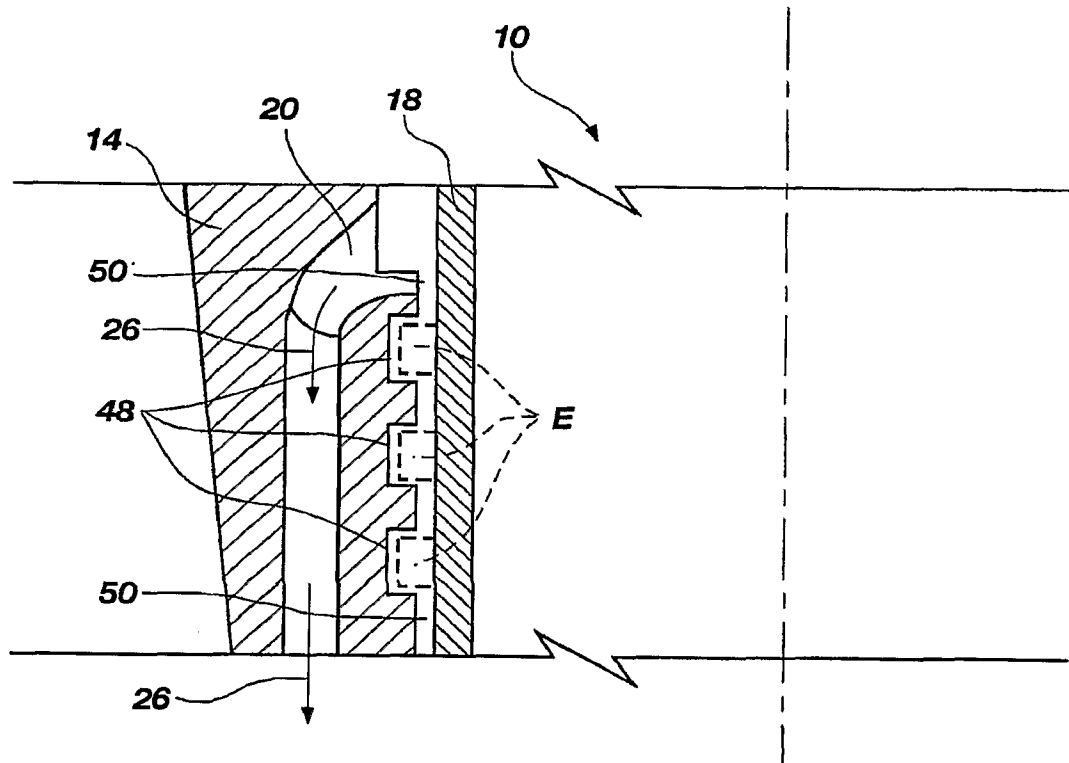


FIG. 5

+

5/5

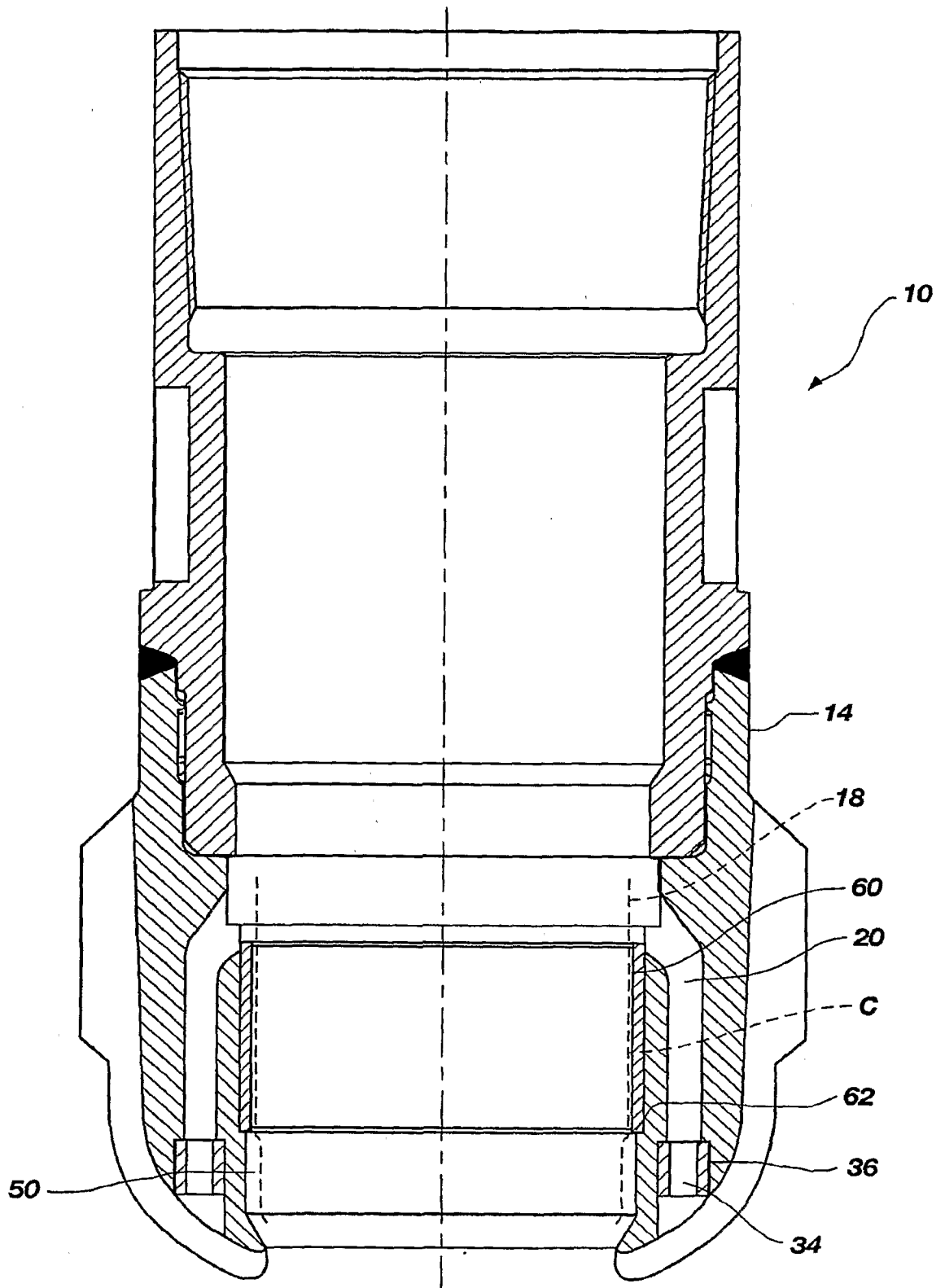


FIG. 6