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(54) Title: DEBRIS COLLECTION DEVICE WITH ENHANCED CIRCULATION FEATURE

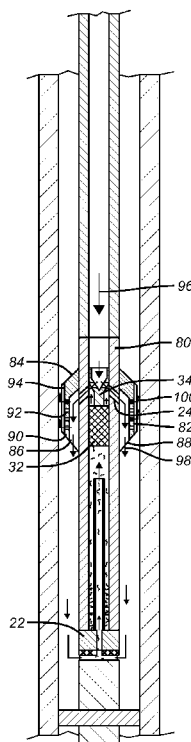


FIG. 4

(57) Abstract: A debris cleanup tool uses an eductor principle to induce flow into a lower end to bring debris into a housing where the debris will either settle out or be screened out and the remaining fluid drawn up into the eductor with motive force for the eductor coming from clean fluid pumped down a tubular string from the surface. The eductor performance is enhanced with a surrounding sleeve on the eductor outlet that directs eductor exhaust flow into an annular passage oriented in a downhole direction. The exterior of the sleeve has passages to allow some of the flow to go uphole while the sleeve wall has ports through it to allow flow in the annular passage to cut through to outside the sleeve for passage uphole or downhole.



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DEBRIS COLLECTION DEVICE WITH ENHANCED CIRCULATION FEATURE

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FIELD OF THE INVENTION

[0001] The field of the invention is debris collection devices for subterranean use and more particularly debris collection devices that use an eductor principle to draw debris laden fluid into a lower end using exhausted eductor fluid where the ability of the eductor to draw fluid is enhanced with an exterior annular path outside the tool housing.

BACKGROUND OF THE INVENTION

[0002] When a metal object, such as a section of casing, a packer, or a lost tool, is to be removed from a well bore, the best method of removal is often to mill the object into small cuttings with a mill such as a pilot mill, a section mill, or a junk mill, and then to remove the cuttings from the well bore. Furthermore, a milling tool will often result in the removal of scale, cement, or formation debris from a hole.

[0003] It is important to remove the cuttings, or other debris, because other equipment subsequently used in the well bore may incorporate sealing surfaces or elastomers, which could be damaged by loose metal cuttings being left in the hole. Most commonly, the metal cuttings and other debris created by milling are removed from the well bore by circulating fluid down the inside of the workstring and out openings in the milling tool, then up the annulus to the surface of the well site. This "forward circulation" method usually leaves some cuttings or debris stuck to the side of the well casing or well bore surface, and these cuttings or debris can damage some of the tools which may subsequently be run into the hole. Also, safety devices such as blow-out preventers usually have numerous cavities and crevices in which the cuttings can become stuck, thereby detracting from the performance of the device or possibly even preventing its operation. Removal and clean-out of such safety devices can be extremely expensive, often costing a quarter of a million dollars or more in the case of a deep sea rig. Further, rapid flow of debris-laden fluid through the casing can even damage the casing surface. Nevertheless, in applications

where a large amount of metal must be removed, it is usually necessary to mill at a relatively fast rate, such as 15 to 30 feet of casing per hour. These applications call for the generation of relatively large cuttings, and these cuttings must be removed by the aforementioned method of "forward circulation", carrying the metal cuttings up to the well site surface via the annulus.

In some applications, such as preparation for the drilling of multiple lateral well bores from a central well bore, it is only necessary to remove a relatively short length of casing from the central bore, in the range of 5 to 30 feet. In these applications, the milling can be done at a relatively slow rate, generating a somewhat limited amount of relatively small cuttings. In these applications where a relatively small amount of relatively small cuttings are generated, it is possible to consider removal of the cuttings by trapping them within the bottom hole assembly, followed by pulling the bottom hole assembly after completion of the milling operation. The advantage of doing so is that the cuttings are prevented from becoming stuck in the well bore or in a blow-out preventer, so the risk of damage to equipment is avoided.

[0004] Some equipment, such as the Baker Oil Tools combination ball type Jet and junk basket, product number 130-97, rely upon reverse circulation to draw large pieces of junk into a downhole junk removal tool. This product has a series of movable fingers which are deflected by the junk brought into the basket, and which then catch the larger pieces of junk. An eductor jet induces flow into the bottom of the junk basket. This tool is typical, in that it is generally designed to catch larger pieces of junk which have been left in the hole. It is not effective at removing small debris, because it will generally allow small debris to pass back out through the basket.

[0005] Moreover, the ability of this tool to pick up debris is limited by the fluid flow rate which can be achieved through the workstring, from a pump at the well site. In applications where the tool must first pass through a restricted diameter bore, to subsequently operate in a larger diameter bore, the effectiveness of the tool is severely limited by the available fluid flow rate. Additionally, if circulation is stopped, small debris can settle behind the

deflecting fingers, thus preventing them from opening all the way. Further, if this tool were to be run into a hole to remove small cuttings after a milling operation, the small cuttings would have settled to the bottom of the hole, making their removal more difficult. In fact, this tool is provided with coring blades for coring into the bottom of the hole, in order to pick up items which have settled to the bottom of the hole.

[0006] Another type of product, such as the combination of a Baker Oil Tools jet bushing, product number 130-96, and an internal boot basket, product number 130-21, uses a jet action to induce fluid flow into the tool laden with small debris. The internal boot basket creates a circuitous path for the fluid, causing the debris to drop out and get caught on internal plates. An internal screen is also provided to further strip debris from the fluid exiting the tool. The exiting fluid is drawn by the jet back into the annulus surrounding the tool. However, here as before, if this tool were to be run into a hole to remove small cuttings after a milling operation, the small cuttings would have settled to the bottom of the hole, making their removal more difficult. Furthermore, here again, the ability of this tool to pick up debris is limited by the fluid flow rate which can be achieved through the workstring.

[0007] Another known design is represented by the Baker Oil Tools Model M reverse circulating tool, which employs a packoff cup seal to close off the wellbore between fluid supply exit ports and return fluid exit ports. A reverse circulating flow is created by fluid supply exit ports introducing fluid into the annulus below the packoff cup seal, which causes fluid flow into the bottom of an attached milling or washover tool. This brings fluid laden with debris into the central bore of the reverse circulating tool, to be trapped within the body of the tool. The reverse circulating fluid exits the body of the tool through return fluid exit ports above the packoff cup seal and flows to the surface of the well site via the annulus. This tool relies upon the separation of the supply fluid and the return fluid, by use of the packoff cup seal between the fluid supply exit ports and return fluid exit ports. To avoid damage to this cup during rotation of the tool, the packoff cup seal must be built on a bearing assembly, adding significantly to the cost of the tool. Additionally, here as

before, the ability of this tool to pick up debris is limited by the fluid flow rate which can be achieved through the workstring.

[0008] As shown in FIGS. 1 and 2, originally in USP 6,276,452, a rotating tool 8 has a drive sub 10 at its upper end, a plurality of sections of wash pipe 12, 16, 18 connected to the drive sub 10, a screen crossover 14 and a triple connection sub 20 connected to the wash pipe, and a milling tool 22 connected to the lower end of the triple connection sub 20. The drive sub 10 is adapted to connect to a rotating workstring (not shown) or to a downhole motor (not shown) connected to a non-rotating workstring, such as coiled tubing, by means such as a threaded connection. The sections of wash pipe 12, 16, 18, the screen crossover sub 14, and the triple connection sub 20 serve as a separator housing. The uppermost wash pipe ejection port section 12, which is threaded to the drive sub 10, incorporates a plurality of supply fluid exit or ejection ports 24 penetrating the wall of the wash pipe section 12 at spaced intervals. The screen crossover sub 14, which is threaded to the ejection port section 12, serves to hold a tubular filter screen 32 in place below the ejection ports 24, with the screen 32 extending downwardly toward the milling tool 22 at the lower end of the apparatus. A first wash pipe extension section 16 can be threaded to the screen crossover sub 14, if necessitated by the length of the screen 32. A second wash pipe extension section 18 is threaded to the first extension section 16. The triple connection sub 20 is threaded to the lower end of the second extension section 18.

[0009] The milling tool 22 is threaded to the lower end of the triple connection sub 20. A plurality of blades 23 are positioned at intervals about the periphery of the milling tool 22 for milling metal items, such as casing or liner pipe, from the well bore. The lower end of the milling tool 22 can have a drift plate 25, which has a diameter close to the inside diameter of the bore hole in which the milling tool 22 will be used. The drift plate 25 serves to prevent metal cuttings from falling down the bore hole. One or more intake slots or ports 26 are provided in the lower end of the milling tool 22 below the blades 23. In applications where the stuck pipe is not concentrically positioned in the casing or well bore, it has been found that the drift plate 25 can break

loose, so in such applications, a milling tool 22 without the drift plate 25 is used, and a single intake port is located at the bottom of the milling tool 22, instead of a plurality of slots 26.

[0010] Importantly, a debris deflector tube 28 is threaded into an interior thread in the triple connection sub 20, extending upwardly from the triple connection sub 20 toward the screen 32. A plurality of side ports 30 are provided through the wall of the deflector tube 28. A deflector plate 31 is provided in the upper end of the deflector tube 28 to deflect any metal cuttings or other debris which might be carried by fluid flowing through the deflector tube 28, and to separate the debris from the fluid. Alternatively, other means of separating the debris from the fluid can be used, such as deflection plates within the deflector tube 28 to create a spiral fluid flow, thereby separating the heavy debris from the fluid.

[0011] Another important feature of the deflector tube 28 is that its reduced diameter facilitates movement of the cuttings along with the fluid, up to the point of separation of the cuttings from the fluid for deposit in a holding area. In a representative example, the body of the tool might have a nominal diameter of 75/8 inches, with the deflector tube 28 having a nominal diameter of 23/8 inches. It has been found that a fluid flow velocity of approximately 120 feet per minute is required to keep the cuttings moving along with the fluid, depending upon the fluid formulation. This flow velocity can be achieved in the exemplary deflector tube 28 with a fluid flow rate of only about 1/2 barrel per minute. If a reverse circulation tool without the deflector tube 28 were employed, a fluid flow rate of about 6 barrels per minute would be required to keep the cuttings moving. Put another way, if a reverse circulation tool were not used, with forward circulation instead being relied upon to move the cuttings all the way to the surface via the annulus, a fluid flow rate of 4 to 10 barrels per minute, or even more, would be required. This means that use of the tool of FIGS. 1 and 2 allows the use of smaller pumps and motors at the well site surface, and use of cheaper formulations of fluid.

[0012] In FIG. 1, a plurality of high speed supply fluid eductor nozzles 34 are provided in the wash pipe ejection port section 12, with each eductor

nozzle 34 being aligned with one of the ejection ports 24, at a downward angle. As the tool 8 is rotated to mill away the metal item from the well bore with the milling tool 22, fluid is pumped by a pump (not shown) at the surface of the well site down through the workstring (not shown). The fluid flows from the workstring through the drive sub 10, and then through the eductor nozzles 34. Since the eductor nozzles 34 have restricted flow paths, they create a high speed flow of fluid, which is then directed downwardly through the ejection ports 24. As the high speed fluid flows out of the eductor nozzles 34 and through the ejection ports 24, it creates an area of low pressure, or vacuum, in the vicinity of the eductor nozzles 34, within the ejection port section 12 of the separator housing.

[0013] This area of low pressure or vacuum in the ejection port section 12 draws fluid up through the intake ports 26 of the milling tool 22, through the deflector tube 28, and through the screen 32. The fluid thusly drawn upwardly then passes out through the ejection ports 24 to the annulus surrounding the separator housing, to flow downwardly toward the milling tool 22. Excess fluid supplied via the workstring can also flow upwardly through the annulus toward the surface of the well site, to return to the pump.

[0014] As fluid flows past the milling tool blades 23, it entrains small cuttings or debris generated as the blades mill away the casing or other metal item. This debris-laden fluid then enters the intake ports 26 at the lower end of the milling tool 22 and passes into the interior of the deflector tube 28 within the wash pipe extension section 18. As the debris-laden fluid exits the side ports 30 in the deflector tube 28, the debris, which is heavier than the fluid, tends to separate from the fluid and settle into an annular area 56 between the deflector tube 28 and the wash pipe extension section 18.

[0015] The fluid, which may still contain very fine debris, then flows upwardly to contact the inlet side of the screen 32. As the fluid flows through the screen 32, the fine debris is removed by the screen 32, remaining for the most part on the inlet side of the screen 32. Fluid leaving the outlet side of the screen 32 then flows upwardly to the area of low pressure, or vacuum, in the vicinity of the eductor nozzles 34.

[0016] This eductor nozzle of FIGS. 1 and 2 will create a sufficient flow velocity to entrain virtually all of the small debris generated by the milling tool 22. In fact, it has been found that a 75/8 inch tool according to the first embodiment creates a sufficient flushing action to remove the cutting debris from a milling operation within a 30 inch casing.

[0017] FIG. 3 illustrates the flow scheme in the device of FIGS. 1 and 2. Arrow 60 represents the pumped flow of clean fluid from the surface. That flow enters ports 34 and exits from ports 24 at an angle to the longitudinal axis of the tool as represented by arrow 62. Upon making the exit there is impingement against the surrounding tubular 64 as some flow goes uphole as shown by arrow 66 and some goes downhole as shown by arrow 68. The result is induced flow through the tool as indicated by arrow 70. The induced flow is also boosted by the flow represented by arrows 68 heading downhole and into the lower end of the mill assembly 22. The cuttings from the milled object 72 enter inlet 26 and mostly settle into the annular volume 56 around the inlet tube 28.

[0018] The problem is that the circulation induced by this layout is not optimal due mostly to the turbulence in the annular space adjacent ports 24 due to impingement against the tubular 64 and the separation of the fluid streams going uphole and downhole represented by arrows 66 and 68 respectively. The present invention addresses this issue with an annular passage that has lateral ports and exterior recesses that also functions as a centralizer. The turbulence reduction allows greater eductor flow through and pressure drop within the eductor to enhance the fluid draw through the eductor. Those skilled in the art will appreciate that other aspects of the invention are further explained in the detailed description of the preferred embodiment and the associated drawings while recognizing that the full scope of the invention is to be determined by the appended claims.

SUMMARY OF THE INVENTION

[0019] A debris cleanup tool uses an eductor principle to induce flow into a lower end to bring debris into a housing where the debris will either settle out or be screened out and the remaining fluid drawn up into the eductor with

motive force for the eductor coming from clean fluid pumped down a tubular string from the surface. The eductor performance is enhanced with a surrounding sleeve on the eductor outlet that directs eductor exhaust flow into an annular passage oriented in a downhole direction. The exterior of the sleeve has passages to allow some of the flow to go uphole while the sleeve wall has ports through it to allow flow in the annular passage to cut through to outside the sleeve for passage uphole or downhole.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] FIG. 1 is a section view of the upper end of a debris removal tool of the prior art;

[0021] FIG. 2 is a section view of the lower end of the tool shown in FIG. 1;

[0022] FIG. 3 is a circulation diagram of the flows in the tool of FIGS. 1 and 2;

[0023] FIG. 4 is a section view of the present invention illustrating the preferred flow scheme.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0024] Interior to the housing **80** the debris removal tool shown in FIG. 4 is similar to the design in FIGS. 1 and 2 described above. The main difference is the shroud **82** that has a closed upper end **84** with outlet **24** being closer to the closed end **84** than an open end **88** and directing flow into an annular passage **86**. Passage **86** has an open downhole oriented end **88**. A wall **90** has a plurality of wall openings **92** that preferably lead into longitudinally oriented grooves **94** that are circumferentially spaced on the outer surface of wall **90**.

[0025] Clean fluid is pumped downhole as represented by arrow **96** and exits into annular passage **86** as the eductor exhaust stream. From there most of the flow continues down passage **86** to the lower end **88** while some of the flow goes through the openings **92**. At the lower end **88** the flow splits as indicated by arrows **98** and **100**. The flow represented by arrow **98** goes to the lower end of the housing **80** to bring debris laden fluid into the mill **22**. The eductor **34** also draws the same fluid through the screen **32**. Some of the fluid coming out of eductor **34** goes uphole through the passages or grooves **94**.

Some flow can go through the wall openings **92** into grooves **94** or to the outer surface of wall **90** adjacent the grooves **94**. The flow that gets to the bottom **98** of the passage **96** at least in part makes a sharp hairpin turn to go through the grooves **94**. The grooves **94** are optional and any number can be used with the cross section being semi-circular, quadrilateral, triangular or some other shape. Alternatively to grooves the wall **90** can be made thick enough to have longitudinal bores instead of grooves **94**. As another option the wall **90** can be made thin enough and the grooves **94** can be eliminated while still leaving an annular passage uphole for some of the circulating fluid to return to the surface.

[0026] The wall openings **92** can have a variety of shapes and distribution patterns. Their purpose is to allow some of the flow to take a short-cut on the way uphole. The holes can be a constant dimension bore or they can be flared toward the outside of the wall **90** to reduce erosion.

[0027] Those skilled in the art will also appreciate that the shroud **82** also functions as a centralizer by having an outer dimension larger than the housing **80**. As an option hard facing can be an exterior feature of the shroud **82** to reduce wear for running in and during mill operation.

[0028] Tests reveal that the presentation of the passage **86** when using the shroud **82** reduces turbulence that otherwise occurs as the exiting flow from the eductor **34** also reduces the total flow through the eductor. With more flow through the eductor a higher debris laden flow stream is maintainable so that the mill **22** runs cooler and the efficiency of debris collection is enhanced. On the other hand the presence of the shroud **82** can also restrict flow trying to go uphole so that the grooves or passages **94** are used to offset that effect. Those skilled in the art will recognize that an optimization of the area of the passage **86** and the return flow to the surface represented by arrows **100** can be undertaken for a given application.

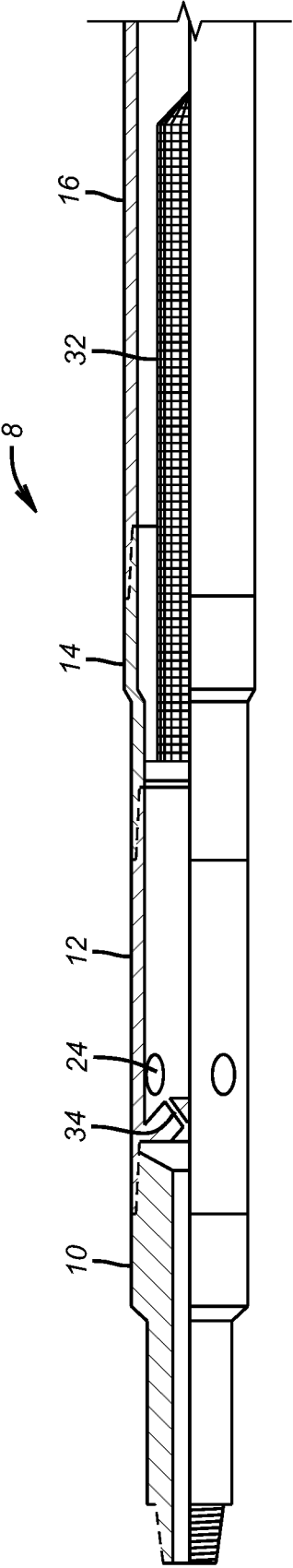
[0029] While a debris cleanup tool is illustrated the present invention has application to other subterranean tools that use an eductor concept to induce circulation.

[0030] The above description is illustrative of the preferred embodiment and many modifications may be made by those skilled in the art without departing from the invention whose scope is to be determined from the literal and equivalent scope of the claims below.

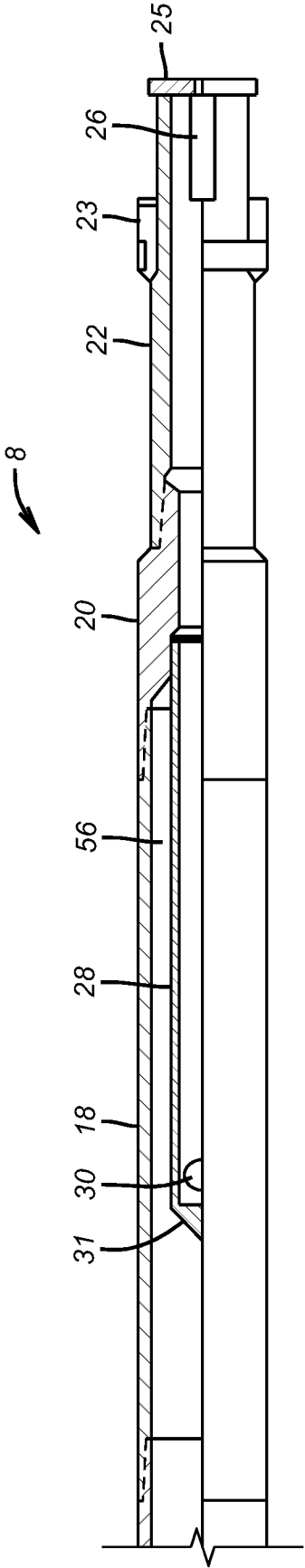
I claim:

1. A tool for subterranean use, comprising:
a housing having a passage therethrough;
an eductor located in said passage for inducing fluid circulation through said passage, said eductor having an outlet leading through a wall of said housing;
a turbulence reducing member mounted adjacent said outlet to enhance the ability of said eductor to induce fluid circulation in said passage.
2. The tool of claim **1**, wherein:
said turbulence reducing member extends from said housing to allow said member to serve as a centralizer for said housing.
3. The tool of claim **1**, wherein:
said turbulence reducing member defines an annular passage about said outlet.
4. The tool of claim **3**, wherein:
said annular passage has a closed end and an opposed open end.
5. The tool of claim **4**, wherein:
said outlet is located closer to said closed end than said open end.
6. The tool of claim **4**, wherein:
said turbulence reducing member comprises a sleeve mounted to said housing where said closed end is defined and spaced from said housing at an opposite end to define a flow outlet.
7. The tool of claim **6**, wherein:
said sleeve comprises a wall defining said annular passage, said wall having at least one opening from said annular passage extending therethrough and between said ends.
8. The tool of claim **6**, wherein:
said sleeve comprises a wall defining said annular passage, said wall having an outer surface and at least one groove on said outer surface.
9. The tool of claim **8**, wherein:
said groove is substantially aligned with a longitudinal axis of said housing.

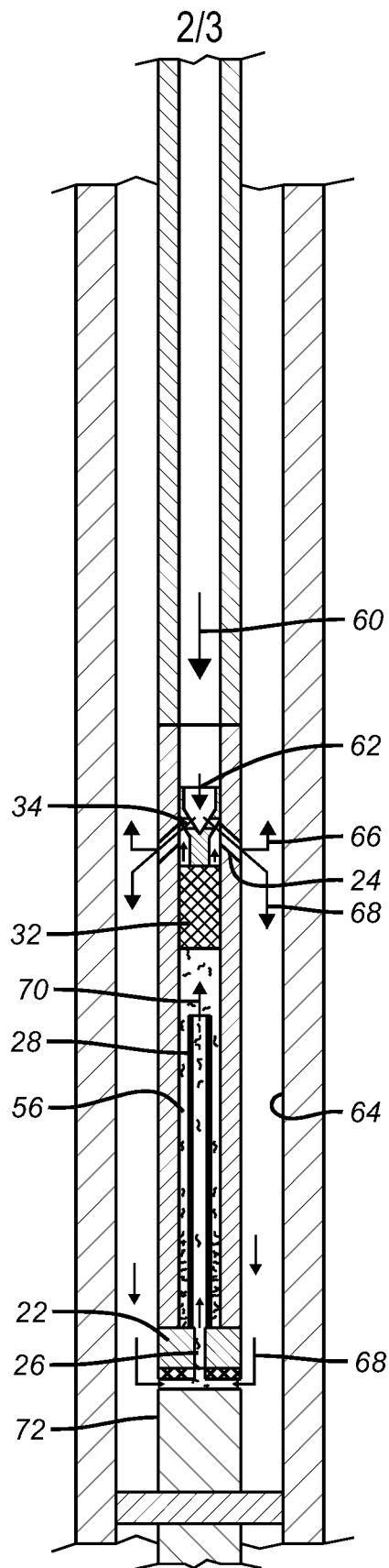
10. The tool of claim **9**, wherein:
said groove has a rounded, quadrilateral or triangular shape in section.
11. The tool of claim **6**, wherein:
said sleeve comprises a wall defining said annular passage, said wall having at least one wall passage therethrough that extends longitudinally between said ends of said sleeve.
12. The tool of claim **11**, wherein:
said wall passage has a rounded, quadrilateral or triangular shape in section.
13. The tool of claim **8**, wherein:
said sleeve comprises a wall defining said annular passage, said wall having at least one opening from said annular passage extending therethrough and between said ends.
14. The tool of claim **13**, wherein:
said opening intersects said groove.
15. The tool of claim **13**, wherein:
said opening is offset from said groove.
16. The tool of claim **11**, wherein:
said sleeve comprises a wall defining said annular passage, said wall having at least one opening from said annular passage extending therethrough and between said ends.
17. The tool of claim **16**, wherein:
said opening intersects said passage.
18. The tool of claim **17**, wherein:
said opening is offset from said passage.
19. The tool of claim **1**, wherein:
said eductor draws debris laden fluid into said housing where at least some of said debris is captured.
20. The tool of claim **14**, wherein:
said eductor draws debris laden fluid into said housing where at least some of said debris is captured.



(PRIOR ART)
FIG. 1



(PRIOR ART)
FIG. 2



(PRIOR ART)
FIG. 3

