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(54) **PULSING APPARATUS FOR DOWNHOLE USE**

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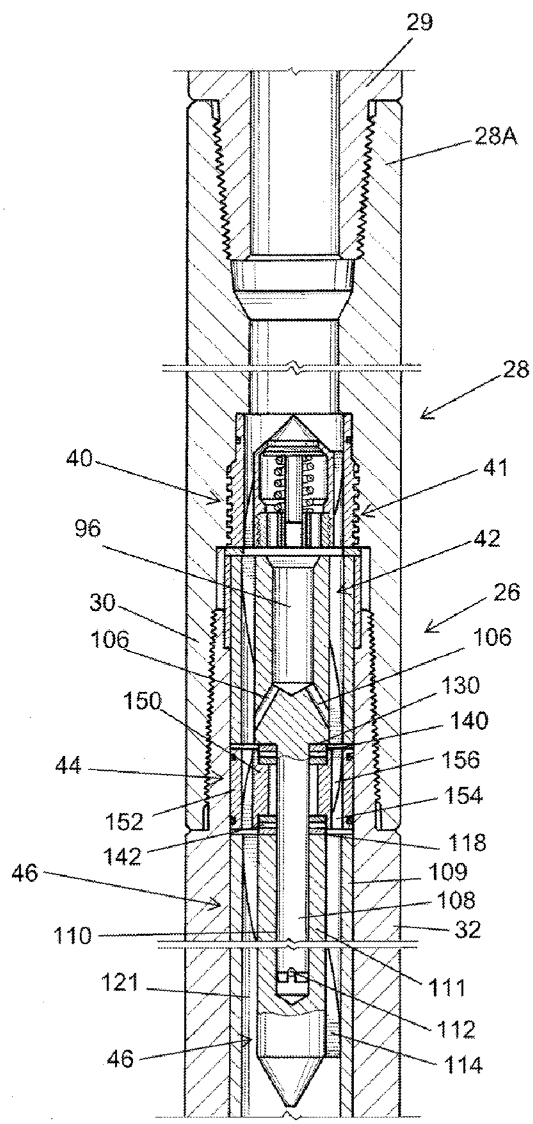
(57) **ABSTRACT**

A pulsing apparatus for use in a conduit through which is flowing a liquid. The pulsing apparatus includes a housing in which is positioned a valve generally at the inlet of the housing, the valve controlling flow of fluid down a central passageway of the housing. There is also flow through an annulus of the housing formed in part by at least one rotor and one stator, the rotor rotating in response to fluid flow impinging on the vanes of the rotor. There is a second valve provided in the lower end of the housing through which flow can be intermittently interrupted to cause pressure pulses in the mud flow and hence in the conduit in which the pulsing apparatus is disposed, the second valve being operatively connected to the rotor.



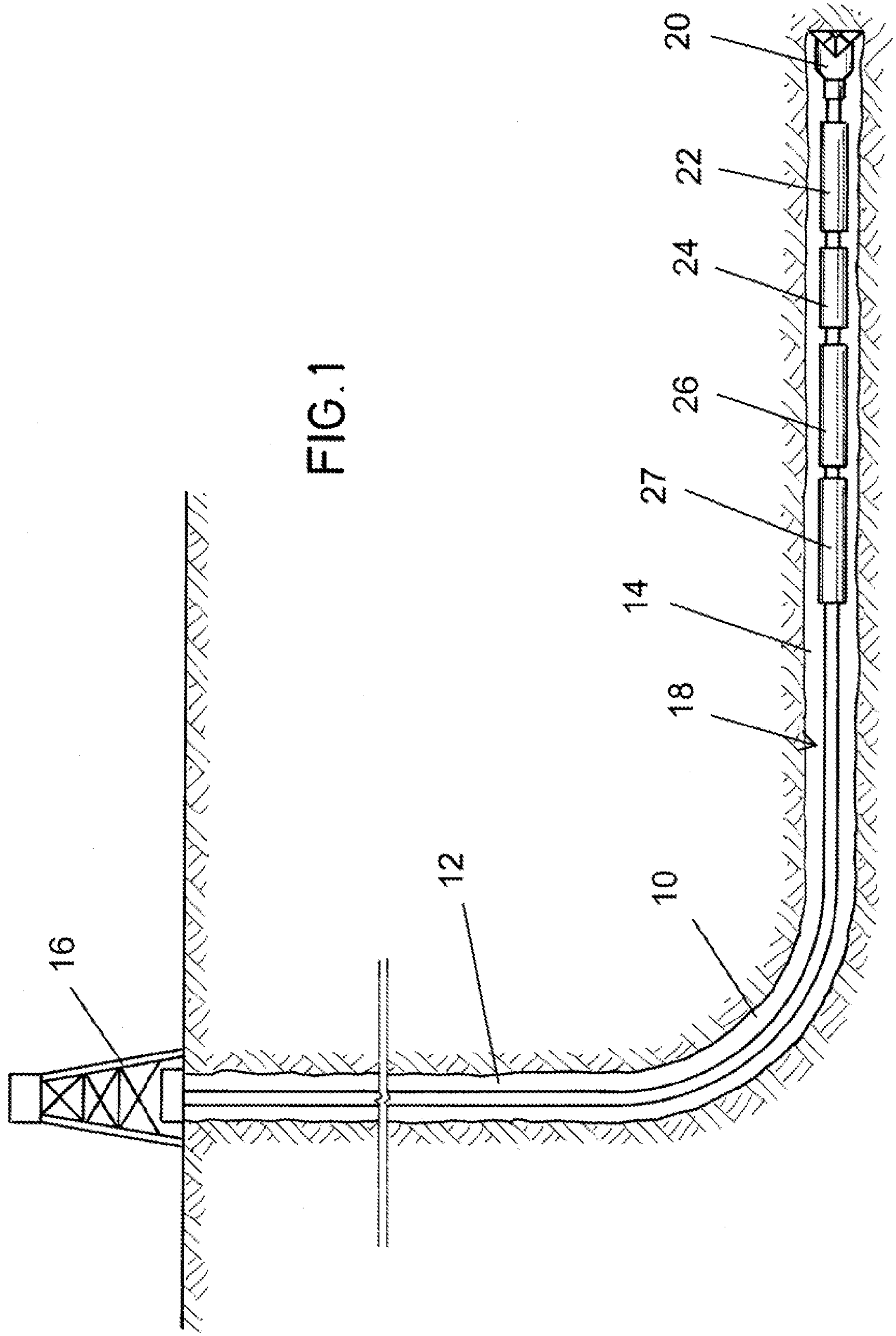
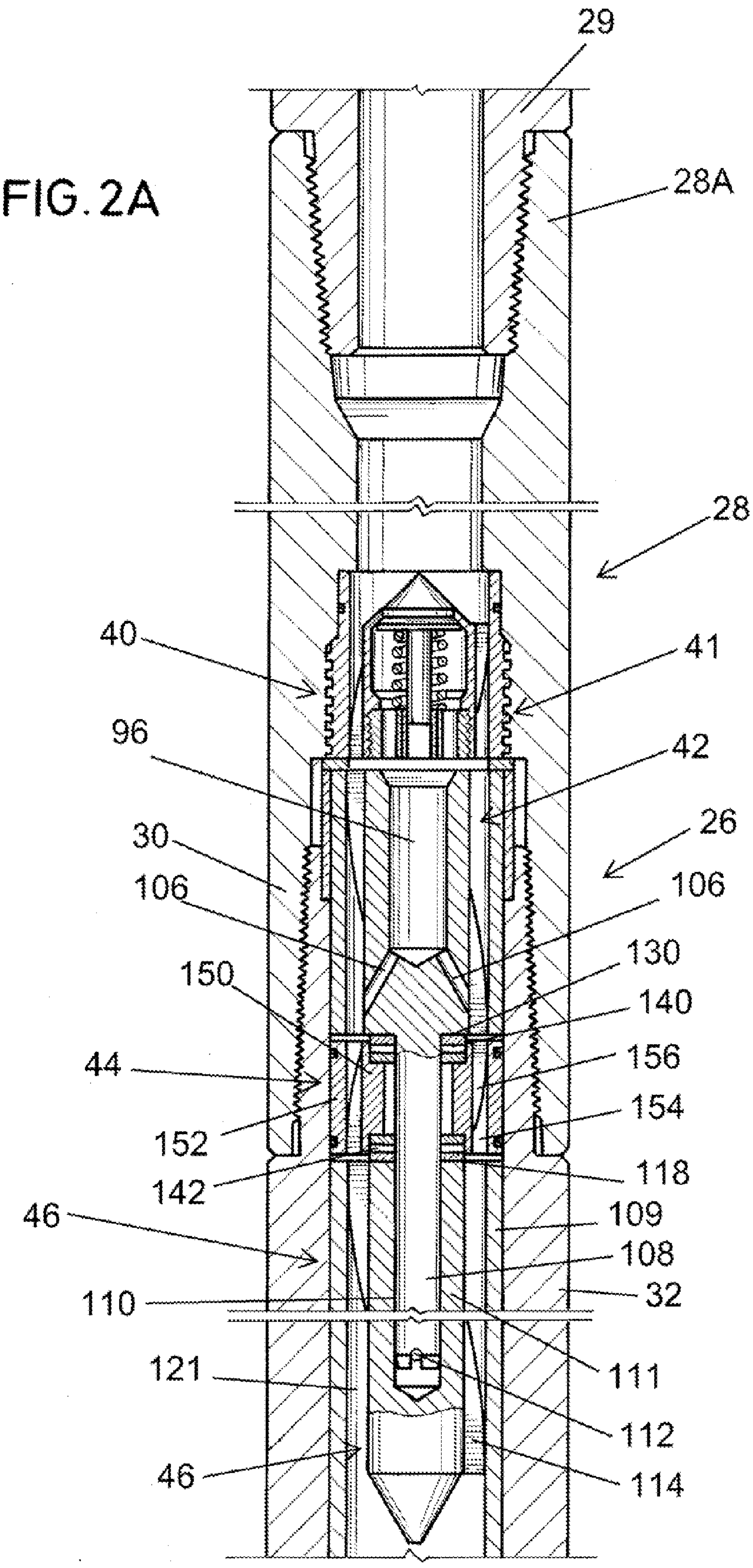


FIG. 1

FIG. 2A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28A
28
40
41
96
42
30
26
106
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44
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121
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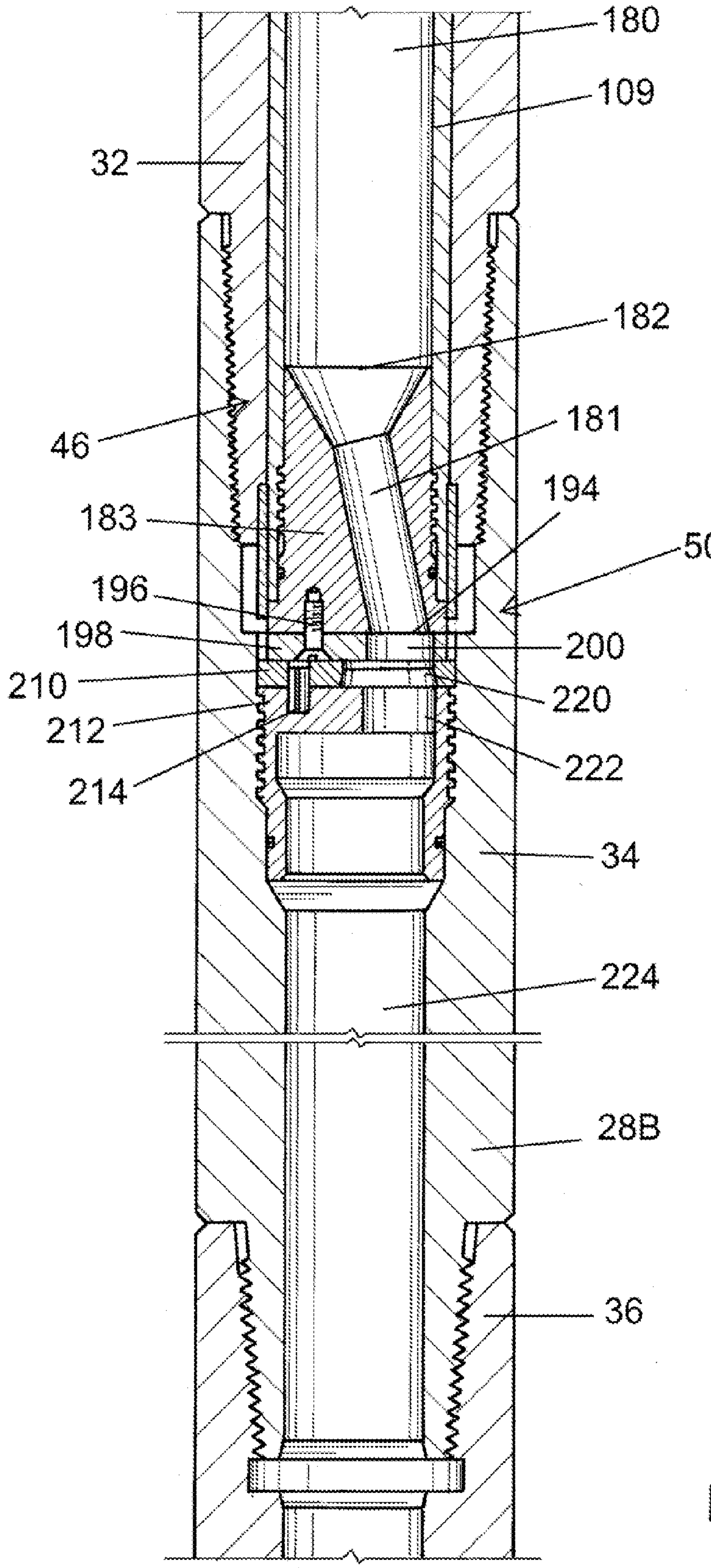
46
114


180
109
32
182
46
181
194
183
50
196
198
200
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220
212
222
214
34
224
28B
36

FIG.2B

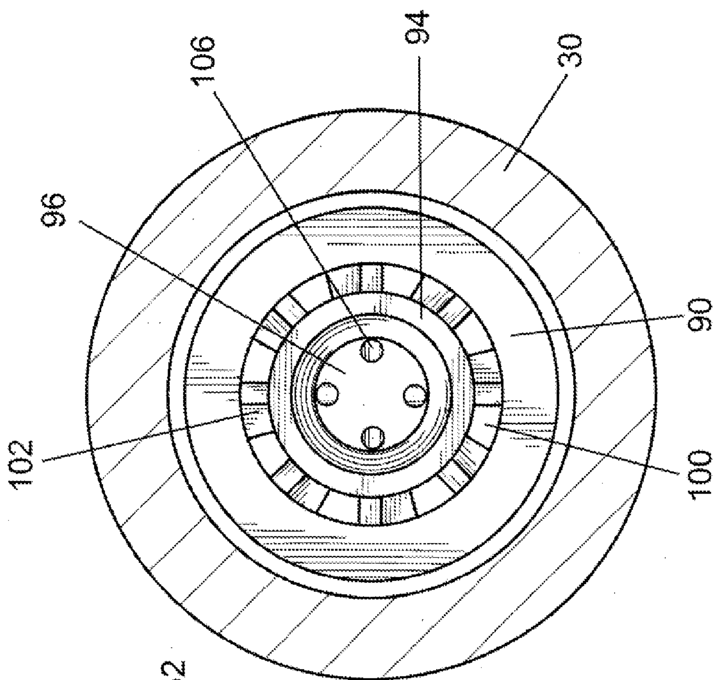
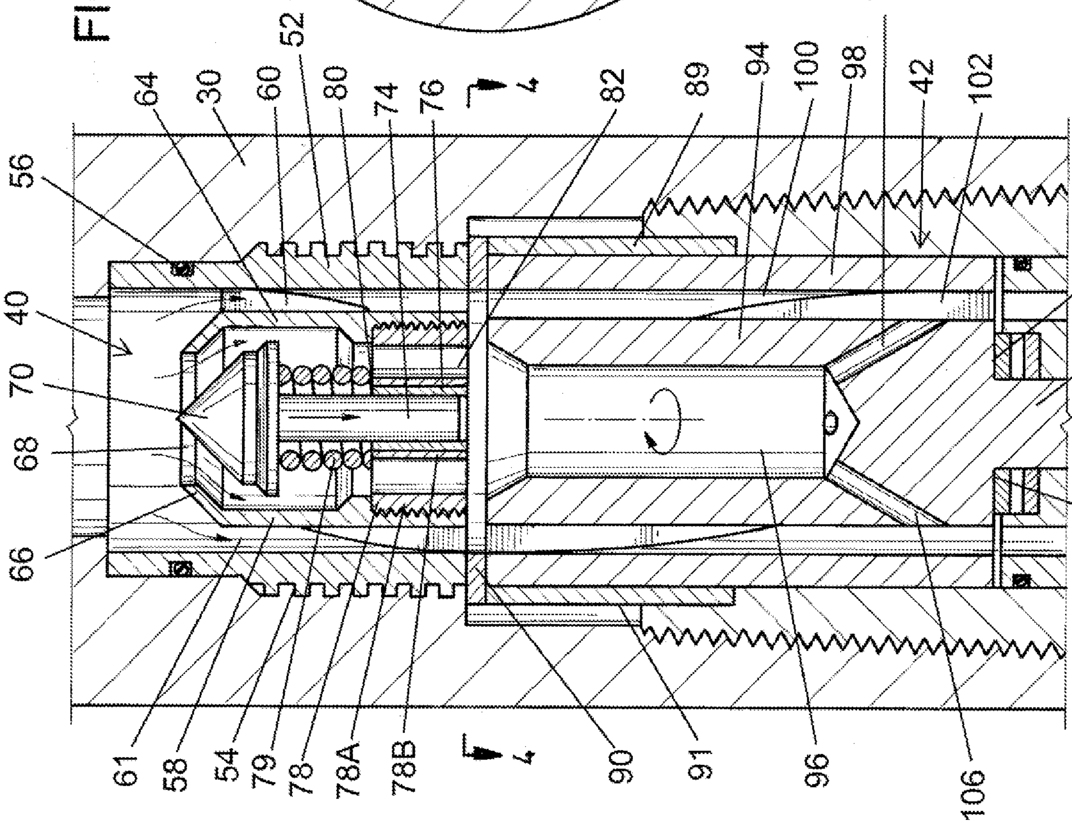

106
94
30
96
90
102
100

FIG. 4


56
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80
74
76
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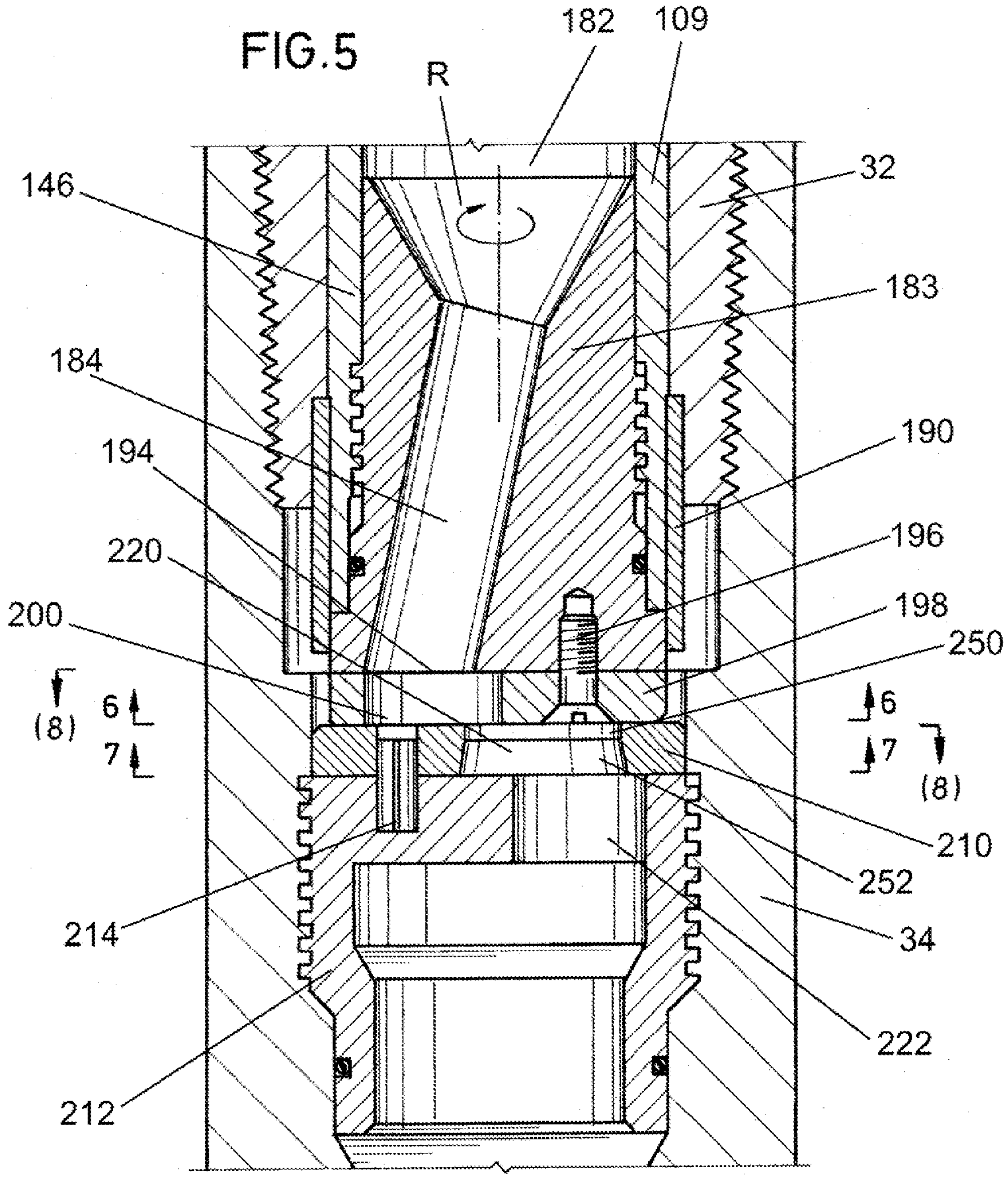
89
94
100
98
106
42
102
108
130
130
130
61
58
54
79
78
78A
78B
4
90
91
96
106

FIG. 3

FIG.5



R
182
109
32
146
183
184
190
194
196
220
198
200
250
6
(8)
7
210
252
214
34
222
212

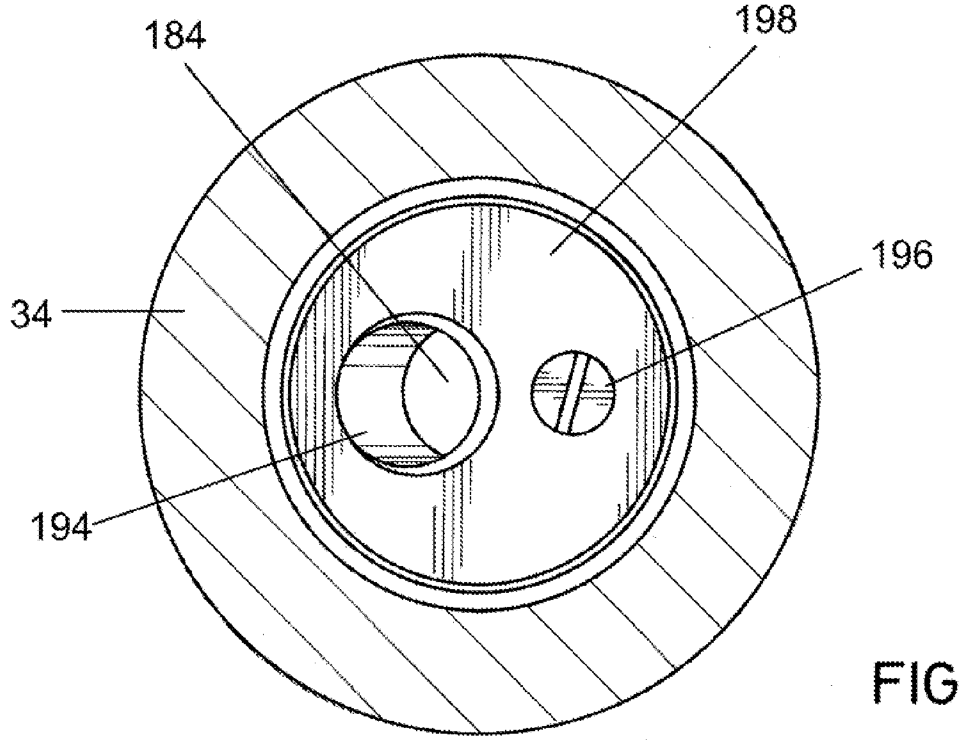

184
198
196
34
194

FIG. 6

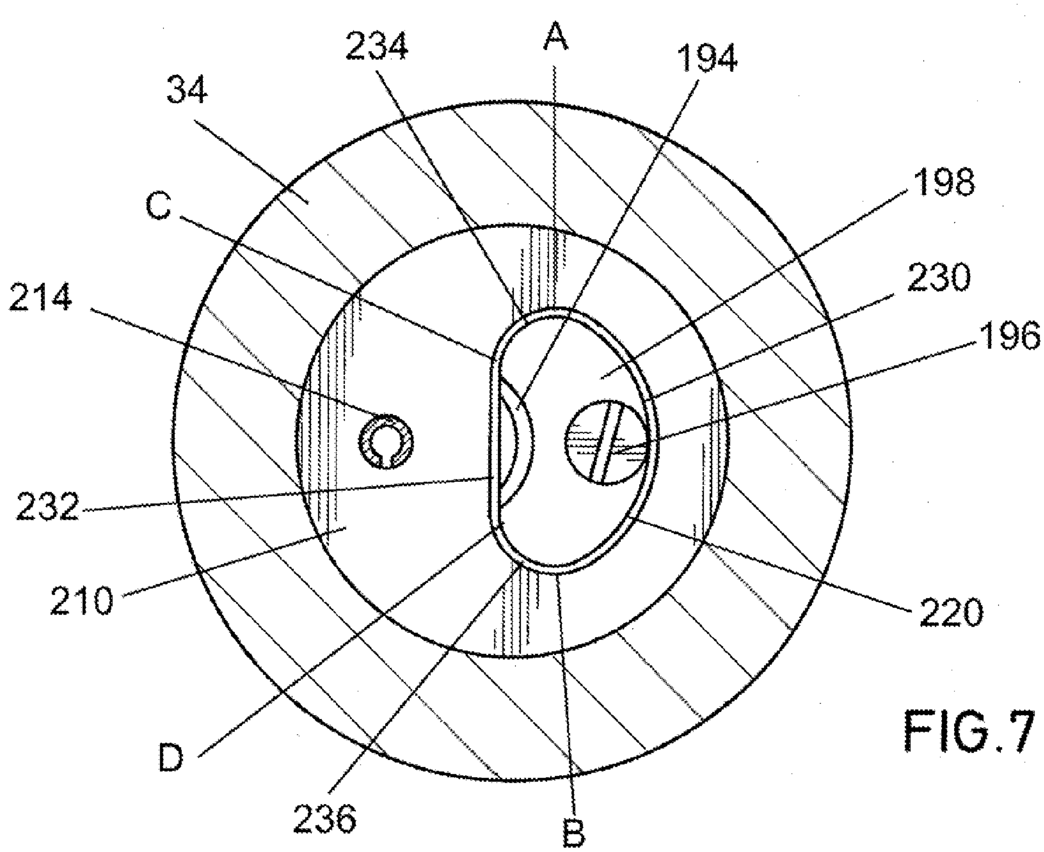

234
A
194
34
198
C
230
214
196
232
210
220
D
236
B

FIG. 7

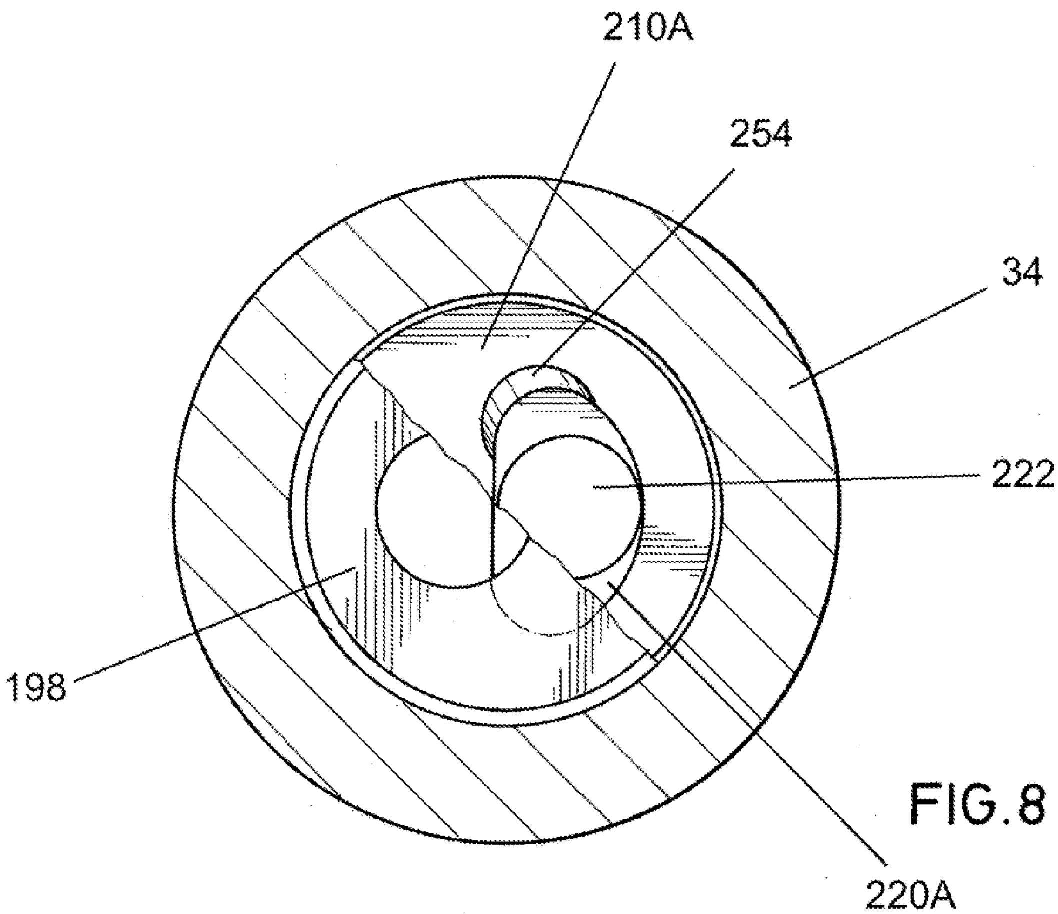


FIG. 8

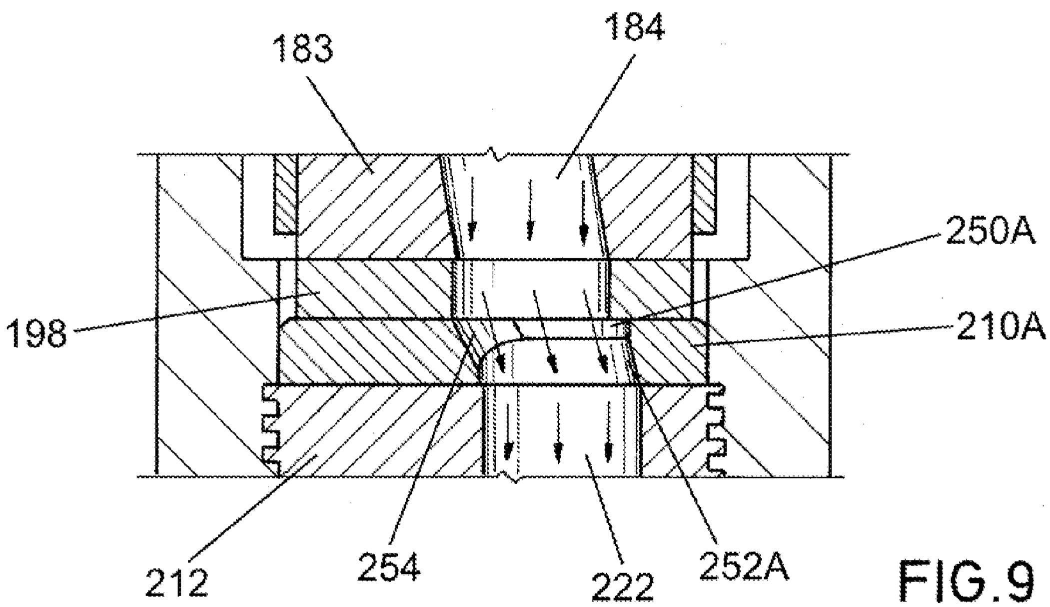


FIG. 9

PULSING APPARATUS FOR DOWNHOLE USE

FIELD OF THE INVENTION

[0001] The present invention relates to flow pulsing apparatus for use in various applications, such as in down-hole operation in oil/gas wells, and in particular to a flow pulsing apparatus adapted to be connected in a drill string above a drill bit.

BACKGROUND OF THE INVENTION

[0002] In the drilling of oil and gas wells as well as other downhole activities, it is common to use a downhole system which provides a percussive or hammer effect to the drill string to increase drilling rate and/or minimize sticking of the drill string in the borehole. In typical drilling operations, a drilling fluid or mud is pumped from the surface, through the drill string and exits through nozzles in the drill bit. The fluid flow from the nozzles assists in dislodging and cleaning cuttings from the bottom of the borehole as well as carrying the cuttings back to the surface.

[0003] Pulsing apparatuses for wellbore activities are well known as exemplified by U.S. Pat. Nos. 2,743,083; 2,780,438; 5,190,114; and 6,279,670. In general, the flow pulses are achieved by periodically restricting flow to produce pressure pulses. The pressure pulses are translated along the drill string causing the drill string to vibrate in a longitudinal direction, the net result being a percussive effect along the length of the drill string.

[0004] It is also common in addition to using the pulsing apparatus to incorporate a pressure-responsive tool in the drill string which expands or retracts in response to the varying fluid pressure pulses created by operation of the pulsing apparatus. This expansion/retraction motion provides the desired percussive effect at the drill bit. Such an apparatus may be in the form of a shock sub or tool and, may be provided above or below the pulsing apparatus or in certain cases can form part of a pulsing apparatus.

SUMMARY OF THE INVENTION

[0005] In one aspect, the present invention provides a downhole pulsing apparatus which can be used to impart periodic, longitudinal movement in the drill string which can be transferred to the drill bit.

[0006] In another aspect, the present invention provides a pulsing apparatus wherein fluid flow through the apparatus can be modulated to control the fluid flow pattern through the pulsing apparatus.

[0007] In still a further aspect, the present invention provides a method of imparting pressure pulses to a drill string wherein the frequency of the pulses can be controlled.

[0008] These and further features and advantages of the present invention will become apparent from the following detailed description, wherein reference is made to the figures in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** schematically depicts a drill string including typical drill string components drilling a deviated borehole.

[0010] FIG. **2**A is an elevational view, partly in section, showing the first, upper end of one embodiment of the pulsing apparatus in accordance with the present invention.

[0011] FIG. **2**B is a view similar to FIG. **2**A showing the second, lower end of the pulsing apparatus of FIG. **2**A.

[0012] FIG. **3** is an enlarged view showing a portion of the pusling apparatus shown in FIG. **2**A.

[0013] FIG. **4** is a cross-sectional view taken along the lines **4-4** of FIG. **3**.

[0014] FIG. **5** is an enlarged view of the lower portion of the pulsing apparatus of FIG. **2**B.

[0015] FIG. **6** is a cross-sectional view taken along the lines **6-6** of FIG. **5**.

[0016] FIG. **7** is a cross-sectional view taken along the lines **7-7** of FIG. **5**.

[0017] FIG. **8** is a plan view taken along the lines (**8**)-(**8**) of FIG. **5**.

[0018] FIG. **9** is a partial elevational view, partly in section, showing the flow of fluid through a portion of the pulsing apparatus depicted in FIG. **8**.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0019] While the invention will be described with respect to its use in a drill string having a downhole motor, it is to be understood that it is not so limited. It can be used in other downhole operations, e.g., drilling with tubulars, or in any other downhole operation involving a tubular string through which a fluid is flowing. Thus the pulsing apparatus of the present invention can be used in work strings, fracking operations, etc.

[0020] Referring then to FIG. **1**, there is shown an earth borehole **10** having a vertical leg **12** and a horizontal leg **14**. Extending from a derrick, mast, or the like **16** at the surface is a drill string shown generally as **18**. String **18** has a series of bottomhole components comprising a drill bit **20** driven by a downhole motor **22**. String **18** also includes a measurement while drilling (MWD) module **24** which can include a steering tool and other sensors commonly employed to determine downhole parameters. Upstring of MWD module **24** is the pulsing apparatus **26** of the present invention, above which is directly positioned a shock sub **27**. The positioning of the pulsing apparatus **26** and the shock sub **27** will vary depending on the nature of the borehole.

[0021] Turning now to FIGS. **2**A and **2**B, the pulsing apparatus **26** comprises a housing shown generally as **28** having a first, upper end **28**A and a second, lower end **28**B. Housing **28** is comprised of a series of threadedly connected subs, namely a first, upper sub **30**, a second sub **32** and a third sub **34**. Sub **30** is connected at its upper end to a drill string element **29** which can be a portion of the drill string, a sub, another tool, etc. Lower sub **34** is also threadedly connected to a drill string component **36**.

[0022] As used herein, and with respect to pulsing apparatus **26**, the terms “upper,” “lower,” “up,” “down,” and similar terms are used with respect to the orientation of the apparatus in an earth borehole.

[0023] The pulsing apparatus **26** further includes a first valve assembly shown generally as **40** and described more fully hereafter, valve assembly **40**, in part, forming a first stator shown generally as **41** and also described hereafter. Below valve assembly **40** is rotatably mounted a first rotor shown generally as **42** also described more fully hereafter. There is a second stator shown generally as **44** positioned below rotor **42** and above a second rotor shown generally as **46**. There is a second valve assembly shown generally as **50** which is positioned in housing **28** below second rotor **46**.

[0024] Referring now to FIGS. **2**A, **2**B, **3**, and **4**, the upper, first end of pulsing apparatus **26** is shown in greater detail. An annular, externally threaded nipple **52** is threadedly received in an internally threaded bore **54** in sub **30**, sealing between sub **30** and nipple **52** being effected by an o-ring seal **56** received in an o-ring groove on the interior wall of sub **30**. As best seen in FIG. **3**, valve assembly **40** comprises a valve body **58**, an annulus **61** being formed between valve body **58** and the inner wall of nipple **52**. A plurality of circumferentially spaced, fixed, angled vanes **60** in annulus **61** connect valve body **58** to nipple **52**. Valve body **58** comprises an annular wall **64** and a frustoconical wall **66**, frustoconical wall **66** defining a circular opening forming an inlet **68** to valve body **58**. Mounted in valve body **58** is a concical shaped plug **70** connected to a spindle **74**, spindle **74** being reciprocally mounted in a sleeve bearing **76**. There is a bushing **78** threadedly received in the lower end of annular wall **64** of valve body **58**. Bushing **78** comprises an outer, annular wall **78**A, and an inner central concentric wall **78**B, inner wall **78**B forming a bearing housing for bearing **76**. An axially upwardly facing, annular shoulder **80** is formed on the upper end of inner wall **78**B. A compression spring **79** is connected to the underside of valve plug **70** and is in surrounding relationship to spindle **74**. In the position shown in FIG. **2**A, conical valve plug **70** substantially blocks valve inlet **68**. However, in the position shown in FIG. **3**, and under the influence of fluid pressure acting against conical valve plug **70**, spring **79** is compressed increasing the flow area between conical valve plug **70** and valve inlet **68**. Accordingly, in the position shown in FIG. **2**A, there is essentially no flow through valve **40**, while in the position shown in FIG. **3** fluid flows through valve **40**. To this end, bushing **78** defines a valve outlet **82**.

[0025] As seen in FIG. **3**, when sufficient fluid pressure caused by mud flow down the drill string from a mud pump (not shown) at the surface is reached, valve **40** opens and there are essentially two flow paths, i.e. a generally central flow path through valve **40** and a radially outer flow path through annulus **61**. It will be recognized by those skilled in the art that vanes **60** act as static guide vanes or nozzle vanes which accelerate and add swirl to the incoming fluid/drilling mud and direct the flow to the vanes of first rotor **42** as discussed hereafter.

[0026] There is a thrust bearing **90** positioned adjacent the lower end of threaded nipple **52**.

[0027] Rotatably journaled in pulsing apparatus **26** is first rotor **42**. Rotor **42** comprises a tubular, central core portion **94** having a central passageway **96**. Passageway **96** communicates with a plurality of angled ports **106** for a purpose described hereafter. Rotor **42** also comprises a radially outward annular sleeve portion **98** connected to and rotatable with core portion **94**, an annulus **100** being formed between core portion **94** and sleeve portion **98**. As seen in FIG. **3**, connecting core portion **94** and sleeve portion **98** are a plurality of circumferentially spaced, angled vanes **102**. The swirling mud flow induced by stator vanes **60** impinges on vanes **102** resulting in rotational motion of first rotor **42**. As well, flow of mud exiting ports **106** from passageway **96** also impinges on vanes **102** resulting in rotation of first rotor **42**. A radial sleeve bearing **89** is positioned in counterbore **91** in surrounding relationship to sleeve portion **98**.

[0028] Central core portion **94** of rotor **42**, as best seen in FIG. **2**A, includes an axially downwardly extending shaft portion **108** which projects toward second, lower end **28**B of housing **28**. Shaft portion **108** is received in an axial bore **110** in the central core portion **111** of a second rotor **46** and is connected thereto by a pin **112** received in registering bores in shaft portion **108** and central core portion **111** of rotor **46**, thereby rigidly connecting rotor **46** to rotor **42** for rotation therewith.

[0029] Sleeve portion **109** of rotor **46** is connected to core portion **111** by a plurality of circumferentially spaced vanes **114** positioned in an annulus **121** between core portion **111** and sleeve portion **109**. Fluid flow in the annulus **121** impinging on vanes **114** induces rotation of rotor **46** in a similar manner as discussed above with respect to rotor **42**.

[0030] The central core portion **111** of rotor **46** has an upper, axially facing surface **118**, while central portion **94** of rotor **42** has an annular, axially downwardly facing shoulder **130**. Disposed between shoulder **130** and the axially upwardly facing surface **118** of rotor **46** is a second stator **44**. Stator **44** carries upper and lower thrust bearing assemblies **140** and **142** respectively and includes a central core portion **150** and a radially outwardly spaced sleeve portion **152** thereby forming an annulus **154** therebetween. Interconnecting core portion **150** and sleeve portion **154** are a plurality of circumferentially spaced, fixed, angled vanes **156**, vanes **156** acting in the same manner as described above with respect to vanes **60** of first stator **40** as a result of fluid flow in annulus **154**.

[0031] As seen in FIG. **2**B, there is a central passageway **180** formed by sleeve portion **109**, passageway **180** being in open communication with a generally radially outwardly angled flowport **181** having a funnel shaped mouth **182** formed in a threaded fitting **183** which is threadedly received in a threaded interior socket of sleeve **109**, fitting **183** rotating in a clockwise direction as indicated by the arrow R shown in FIG. **5**.

[0032] Since flowport **181** exits fitting **183** through an exit opening **194** off-center, as rotor **46** rotates concentrically, flowport **181** moves in an eccentric path. Connected to the lower end of fitting **183** by a threaded bolt **196** is a plate **198** through which extends an opening **200** which is also off-center with respect to the centerline of plate **198**. As seen in FIG. **5**, opening **200** is in open communication with exit opening **194** from flowport **181**. Thus, as rotor **46** rotates, opening **200** also rotates in an eccentric pathway.

[0033] There is a second, annular plate **210** which is connected to a threaded fitting **212** received in a threaded female receptacle in sub **34**. In this regard, as seen in FIG. **5**, plate **210** and fitting **212** have registering bores, offset from the centerline, in which is press fitted a slotted tubular pin **214**. Plate **210**, as seen in FIGS. **5** and **7**, has an offcenter opening **220**, opening **220** being in open communication with a passageway **222** which in turn is in open communication with a central fluid passageway **224**, passageway **224** defining an exit for fluid passing through pulsing apparatus **26** in a downhole direction.

[0034] As best seen in FIG. **6**, opening **220** is generally crescent-shaped. More specifically opening **220** has a modified crescent shape comprised of a generally semi-circular portion **230** which extends from about point A to about point B, a straight portion **232** which extends from about point C to about point D, a first arc portion **234** which extends between point A and point C and a second arc portion **236** which extends between point B and point D. Opening **220** can also be described as bean-shaped, kidney-shaped, etc. As seen in FIG. **5**, the passageway defining opening **220** has a first, upper, vertical wall portion, the wall surface being generally parallel to the long axis of the pulsing tool **26**, and second lower skirt portion **252** which, as seen in FIG. **5**, flares outwardly from the intersection of skirt portion **252** with upper portion **250**.

[0035] FIGS. **8** and **9** show a modified version of opening **220** as indicated by the section lines (**8**)-(**8**). Turning then to FIGS. **8** and **9**, it can be seen that crescent-shaped opening **220**A has a chamfered lip portion **254** extending from the upper surface of plate **210**A downwardly, chamfer **254** extending for approximately a peripheral distance determined by points A and C. In all other respects, as seen in FIG. **9**, the passageway forming opening **220**A is the same as described above with respect to opening **220**.

[0036] As can be best seen by comparing FIGS. **5** and **6**, at all times there is some overlap between fixed opening **220** and eccentrically rotating opening **194**. This ensures that at all times while the mud pumps are operating, there is fluid flow through the drill string. It will also be appreciated that as rotor **46** rotates, the degree of overlap between openings **220** and **194** will vary, resulting in flow changes and hence pressure pulses resulting in pulsing of mud passing through pulsing apparatus **26**.

[0037] In operation, but prior to the mud pumps being turned on, there would of course be no flow through pulsing apparatus **26**. However, activation of the mud pumps forces drilling mud or fluid down the drill string. When the pressure of the flowing mud reaches a predetermined pressure, valve **40** opens, the degree of opening depending upon the pressure of the mud and the spring force of the spring **79**. At the same time, and as can be seen from the above description, there is also flow through an annular path defined primarily by the annuli formed by the rotors and stators. Thus, the above referenced central flow path, at least in part is formed by passageways **96** and **180**.

[0038] The angles of the vanes in rotors/stators can vary to at least partially control the velocity of the mud through the annular flow path. Thus, all the vanes of all the rotors/stators can be at the same angle or at slightly different angles. Likewise, flow through the central passageway commencing with valve **40** is controlled not only by mud pump pressure but also by the spring force of spring **79** determined by the spring constant.

[0039] It will also be appreciated that the plug valve, i.e., valve **40** can be used to more readily control flow through the central passageway of the first stage to the second stage of the pulsing apparatus **26**. In this regard, the conical shape of valve plug **70** coupled with the valve inlet **68** being formed by a frustoconical wall ensures greater throttling control of fluid flow through the central passageway. This is important since speed of rotation of the rotors in the pulsing apparatus **26** is primarily a function of flow through the annular flowpaths. To control rotation, and hence frequency of pulsing, that flow must be modulated which is accomplished by valve **40**.

[0040] Although the application has been described above with respect to a two-stage pulsing apparatus, a stage being a stator and a rotor, it is to be understood that it is not so limited. The pulsing apparatus could include only one stage, two stages as described, or more stages. Furthermore, it will be recognized that the stator vanes impart a spiraling flow path which ensures the fluid impinges on the rotor vanes at the optimum angle of attack.

[0041] It will be understood from the above description that flow exiting pulsing apparatus **26** is in the form of a series of pressure pulses. These pressure pulses are used to provide a percussive action along the axis of the drill string **12**. Furthermore, the fluctuations in the drilling fluid flow rate at drill bit **20** provide for effective cleaning of cuttings from the drill bit during the drilling operation.

[0042] The pressure pulses may also be used, as is well known to those skilled in the art, to operate shock subs or to move a reciprocating mass which impacts on an anvil, with the aim of providing a percussive or hammer action to a system drilling in hard rock. Shock subs useful with the pulsing apparatus of the present invention are well known to those skilled in the art.

[0043] In addition to its uses in drilling, the pulsing apparatus of the present invention can be used in such operations as: (a) reducing friction in drilling operations; (b) shaking of tubing to clean screens; (c) vibrating of cement during cementing operations; (d) pulsating fluid being pumped into a formation to fracture it; (e) enhancing the fishing operation through inducing impulse vibration to the drill string.

[0044] Although specific embodiments of the invention have been described herein in some detail, this has been done solely for the purposes of explaining the various aspects of the invention, and is not intended to limit the scope of the invention as defined in the claims which follow. Those skilled in the art will understand that the embodiment shown and described is exemplary, and various other substitutions, alterations and modifications, including but not limited to those design alternatives specifically discussed herein, may be made in the practice of the invention without departing from its scope.

What is claimed is:

1. A downhole pulsing apparatus comprising:

an elongate tubular housing having a first end and a second, there being an axial fluid flow pathway through said housing;

a first valve disposed proximal said first end of said housing to at least partially control the flow of fluid through said housing, said first valve having a valve inlet and a valve outlet;

at least one vaned stator having a plurality of circumferentially spaced, angled first vanes to direct fluid entering said first end of said housing in a spiral pattern;

at least one vaned rotor rotatably mounted in said housing below said at least one stator, said rotor having a central fluid passageway in fluid communication with the outlet of said valve, said rotor having a plurality of circumferentially spaced, angled second vanes rotatable with said rotor, flow from said stator impinging on said rotor vanes resulting in rotation of said first rotor;

a second valve mounted in said housing, said second valve having first and second valve members, each of said valve members having first and second axial flow openings, respectively, said first valve member being rotatable around a longitudinal axis through said housing, said second valve member being fixed, rotation of said first valve member varying the alignment of said first and second openings between a minimum open area and a maximum open area to provide a an intermittently varying flow and pressure exiting said second end of said housing.

2. The pulsing apparatus of claim **1**, wherein said first valve member is operatively connected to said first rotor for rotation therewith.

3. The pulsing apparatus of claim **1**, wherein there are a plurality of said rotors.

4. The pulsing apparatus of claim **3**, wherein there are a plurality of stators, respective ones of said rotors being positioned below respective ones of said stators.

5. The pulsing apparatus of claim **4**, wherein said first valve member of said second valve is operatively connected to the rotor most proximal said second end of said housing.

6. The pulsing apparatus of claim **1**, wherein said first valve comprises an annular valve body, said annular valve body defining said valve inlet, and a valve element mounted in said valve housing, said valve element comprising a valve plug connected to a compression spring, said valve plug substantially preventing fluid flow into said valve inlet when said spring is in a relaxed position, fluid flowing through said housing acting on said valve plug to compress said spring and increase the flow through said valve inlet.

7. The pulsing apparatus of claim **6**, wherein said valve plug is conically shaped.

8. The pulsing apparatus of claim **1**, wherein said at least one rotor comprises a first central core portion in surrounding relationship to said central passageway and a first outer sleeve, a first rotor annulus being formed between said first central core portion and said first outer sleeve, said second vanes being disposed between and interconnected to said first central core portion and said first outer sleeve.

9. The pulsing apparatus of claim **8**, further comprising a plurality of angled ports in open communication with said central passageway and said first rotor annulus.

10. The pulsing apparatus of claim **8**, wherein said first central core portion of said at least one rotor is connected to a second rotor for rotation therewith, said second rotor comprising a second central core portion and a second outer sleeve, a second rotor annulus being formed between said second central core portion and said second outer sleeve, the vanes of said second rotor being disposed in said second rotor annulus.

11. The pulsing apparatus of claim **8**, wherein said central core portion includes an axially extending shaft portion and said second rotor has an axially extending bore for receipt of said shaft.

12. The pulsing apparatus of claim **11**, wherein said shaft is connected to said second central core portion by a pin received in registering holes in said shaft and said second central core portion.

13. The pulsing apparatus of claim **6**, wherein said valve body has a generally cylindrical portion and a generally frustoconical portion, said frustoconical portion defining said valve inlet.

14. The pulsing apparatus of claim **1**, wherein said second axial flow opening in said second valve member is generally crescent-shaped when viewed in plan view.

15. The pulsing apparatus of claim **14**, wherein said generally crescent-shaped opening forms the mouth of a passageway extending through said second valve member, said second valve member comprising a disc-shaped plate having an upper surface proximal said first valve member, said passageway through said second valve member having a chamfered lip portion extending from said upper surface into said passageway, said lip portion extending for a portion of the periphery of said crescent-shaped opening.

16. The pulsing apparatus of claim **1**, wherein said first valve member comprises a second disc shaped plate.

* * * * *