



- (51) International Patent Classification: Not classified
- (21) International Application Number: PCT/GB2012/051096
- (22) International Filing Date: 16 May 2012 (16.05.2012)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data: 1108252.6 17 May 2011 (17.05.2011) GB
- (71) Applicant (for all designated States except US): **RUFF PUP LIMITED** [GB/GB]; Axholme House North Street, Crowle, Scunthorpe, North Lincolnshire DN17 4NB (GB).
- (72) Inventor; and
- (75) Inventor/Applicant (for US only): **ALLEN, Anthony** [GB/GB]; c/o Ruff Pup Limited, Axholme House North Street, Crowle, Scunthorpe, North Lincolnshire DN17 4NB (GB).
- (74) Agent: **W.P. THOMPSON & CO.**; Coopers Building, Church Street, Liverpool, Merseyside L1 3AB (GB).
- (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, 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,

[Continued on next page]

(54) Title: PERFORATING DRILL STRING ASSEMBLY

(57) Abstract: A perforating drill string assembly comprises a bridge plug (12) connected to a conventional setting tool (14), a casing brush or scraper (20) connected to the lower end of the bridge plug and an explosive perforating gun (36) connected to the casing brush or scraper (20). The bridge plug (12) is secured to a well casing (10) in an area previously cleaned by the casing brush or scraper (20) and the perforating gun (36) is detonated. Preferably, damping means (38, 60) are located between the perforating gun (36) and the casing brush or scraper (20) to reduce the force transmitted to the bridge plug on detonation of the perforating gun.

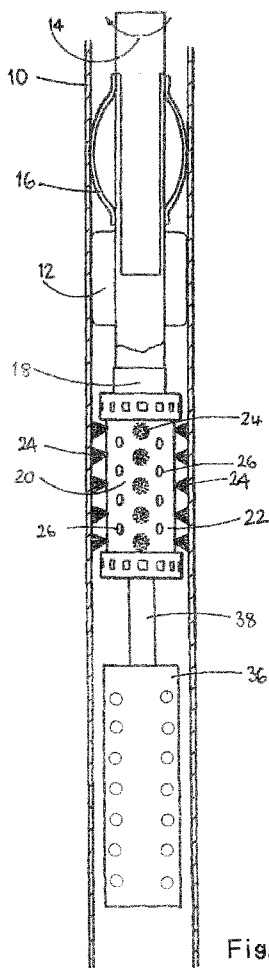


Fig. 1





OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

**(84) Designated States** (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,

**Published:**

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

DESCRIPTIONPERFORATING DRILL STRING ASSEMBLY

The present invention relates to perforating drill string assemblies and in particular to perforating drill string assemblies for use in oil and gas wells.

Perforating drill string assemblies (e.g. the Drill Gun™ device made by Halliburton) are cylindrical or tubular explosive charges that are lowered into oil or gas well casings and are ignited in order to blow holes into the casing in order to allow formation contents (oil/gas/water or any mixture of these) to flow into the casing for upward transmission to the surface. Also, after formation of the holes in the casing, well cementation, acidising or other operations may be carried out either from inside the casing to the formation or from the formation into the casing (for example flow tests, pressure tests etc.).

Known perforating drill string assemblies are attached to the lower end of a packer and are lowered down the casing. The packer may be a drillable temporary packer, a retrievable packer or a permanent packer. In all cases, the packers may have metal or composite gripping slips and rubber sealing elements which seal the casing above and below the packer. In addition, the slips grip the inside of the casing to ensure that the packer stays in the desired position.

In order to ensure that the packer does not leak past the seals, it is desirable to run a cleaning brush into the region of the casing where the packer is to be positioned. This usually involves running a well casing

scraper or brush through the well casing to remove dirt and debris adhering to the walls of the casing. However, the cleaning operation can add several hours to the overall operation, which represents a loss of rig operating time. In addition, it is possible for the intended site of the well  
5 packer to be recontaminated between cleaning by the scraper or brush and positioning of the packer at the desired location.

It is an object of the present invention to provide a perforating drill string assembly which does not require a separate cleaning run to be carried out on the well casing.

10 In accordance with a first aspect of the present invention, a perforating drill string assembly comprises a bridge plug, a casing brush or scraper connected to the lower end of the bridge plug and an explosive perforating gun connected to the casing brush or scraper.

In use, the assembly is inserted into the well casing. The casing  
15 brush or scraper below the bridge plug cleans the wall of the well casing and ensures a clean surface against which to set the bridge plug in place. Once the bridge plug has been secured in position in the well casing, the perforating gun can be detonated, thereby rupturing the well casing below the bridge plug.

20 Preferably, the perforating drill string assembly further comprises elongate connecting means, extending between, and connecting, the casing brush or scraper and the perforating gun.

Preferably, the elongate connecting means comprises damping means.

The length of the elongate connecting means is preferably adjustable.

Preferably, the elongate connecting means is adapted to be compressed on detonation of the perforating gun by the resultant upward  
5 well fluid pressure surge caused by said detonation.

In a preferred embodiment, the elongate connecting means comprises first and second elongate members slidably mounted with respect to each other, each of the first and second elongate members being connected to a respective one of the casing brush or scraper and  
10 the perforating gun.

One of the first and second elongate members may be slidably disposed within the other of the first and second elongate members.

The perforating drill string assembly preferably further comprises damping means for resisting relative displacement of the first and second  
15 elongate members upon detonation of the perforating gun.

The damping means may comprise a deformable member which is deformed when the elongate connecting means is compressed.

Preferably, the damping means comprises a plurality of deformable members which are deformed when the elongate connecting means is  
20 compressed, e.g. a stack of deformable members.

The perforating drill string assembly may further comprise means for limiting compression of the elongate connecting means on detonation of the perforating gun.

The means for limiting compression may comprise one or more grooves in one of the first and second elongate members which receive a projection secured to the other of the first and second elongate members.

In one embodiment, the elongate connecting means comprises an elongate casing and piston means slidably disposed in the elongate casing, each of the elongate casing and the piston means being connected to a respective one of the casing brush or scraper and the explosive perforating gun.

The elongate connecting means preferably comprises one or more deformable members which are deformed when the piston means is displaced.

Preferably, the one or more deformable members are located between the piston means and a portion fixed with respect to the casing and the or each deformable member is preferably annular.

The casing preferably comprises one or more fluid outlet ports.

The or each fluid outlet port is preferably mounted at or towards an upper end of the casing.

Preferably, the axis of the or each outlet port is inclined to the longitudinal axis of the casing.

The or each fluid outlet port may comprise means for preventing exhaust of fluid at pressures below a threshold value.

The means for preventing exhaust of fluid may comprise a bursh disc and/or a non-return valve.

The casing preferably also comprises one or more fluid inlet valves.

Preferably, the or each fluid inlet valve is closed by movement of the piston means.

In this way, a fixed volume of fluid is isolated within the casing, which damps the further upward movement of the piston means, the fluid  
5 being discharged from the casing via the exhaust ports.

By way of example only, specific embodiments of the present invention will now be described with reference to the accompanying drawings, in which:

Fig. 1 is a longitudinal cross-section through an embodiment of  
10 perforating drill string assembly in accordance with the present invention, located within a well casing;

Fig. 2 is a cross-section through the upper end of a brush portion of the perforating drill string assembly, to a larger scale;

Fig. 3 is a cross-sectional view through an extension tube which  
15 forms part of the perforating assembly of Figs. 1 and 2;

Figs. 4 and 5 are longitudinal cross-sections through a modification to the perforating drill string assembly of Figs. 1 to 3, shown in pre-detonation and post-detonation configurations respectively; and

Figs. 6 and 7 are longitudinal cross-sections through modifications  
20 of the perforating drill string assembly of Figs. 4 and 5.

A perforating drill string assembly for use with a drill casing 10 comprises a drillable bridge plug or packer 12 connected to a conventional setting tool 14. The setting tool 14 has spring loaded blocks 16 which grip

the inside of the well casing 10 to hold the outside of the bridge plug 12 from any rotation during installation, as will be explained.

The lower end of the bridge plug is connected, via an adapter 18, to a well casing brush 20. The well casing brush comprises a tubular central  
5 body 22 having a plurality of groups of cleaning bristles 24 embedded in its outer wall. The cleaning bristles 24 are conveniently formed of non-ferrous material, but the present invention is not restricted in this way. The central body 22 comprises a drillable material such as, for example, aluminium, cast iron or any soft alloy. In the context of the present  
10 invention a drillable material is any material which can be drilled by a well bore drilling bit and, in particular, a rock bit. Since a rock bit is the least suited of such bits for drilling out a well casing it follows that if the material can be drilled by a rock bit it can also be drilled out by any other type of bit including a PDC bit. Holes 26 are also provided in the outer wall of the  
15 central body 20 through which cleaning fluid can be pumped to assist the cleaning action of the bristles 24.

The adapter 18 facilitates connection to the lower end of the drillable bridge plug 12 and is chosen to suit the particular drillable bridge plug with which it will be used. In this particular embodiment, the adapter  
20 comprises a torque-free swivel. As will be seen from Fig. 4, the adapter 18 is received within an enlarged section of the through bore in the casing brush and is held in place by means of pins 28, each of which passes through a hole in the casing into a circumferential channel 30 in the adapter. As shown, the adapter is able to rotate relative to the casing.



However, by inserting a longer pin 32 into a hole 34 in the bottom of the channel the adapter and casing can be locked together.

An explosive perforating gun 36 is located below the casing brush 20. The perforating gun 36 is generally conventional and comprises a cylindrical or tubular explosive charge. The perforating gun is connected to the casing brush by means of an extension tube 38 which, as will be explained, provides a damping function between the perforating gun 36 and the casing brush 20 on detonation of the perforating gun. As best seen in Fig. 2, the upper end 40 of the extension tube is screw-threadedly received in a corresponding threaded recess 42 in the undersurface of the adapter 18. Similarly, the lower end of the extension tube 38 is provided with a screw-threaded recess 44 which is adapted to screw-threadedly receive a complementarily-screw-threaded boss (not shown) on the upper end of the perforating gun 36.

As best seen in Fig. 3, the extension tube 38 between the casing brush and the perforating gun comprises a lower, outer tube 38a which screw-threadedly connects to the perforating gun via the screw-threaded recess 44 and an upper, inner tube 38b which is telescopically-received within the lower tube 38a and whose upper end 40 is screw-threadedly connectible to the adapter 1, as described previously. A plurality of pressure seals 46 is located between the outer and inner tubes 38a, 38b of the extension tube. In addition, the outer face of the inner tube 38b is provided with a plurality of longitudinally-extending grooves 48, each of

which receives a radially inwardly projecting peg 50 projecting from the inner face of the upper end of the outer tube.

It will also be noted that a plurality of resilient damper rings 52a to 52e are located between the lower end of the inner tube and a radially-inwardly directed shoulder in the outer tube. The radius of the hole in the damper rings increases stepwise from the uppermost ring 52a to the lowermost ring 52e.

In use, the perforating drill string assembly is lowered into a well by attaching the setting tool 14 to a conventional drill string (not visible). When the desired setting depth is reached, the assembly may be moved up and down and cleaning fluid may be injected from the drilling brush 20 into the area to be cleaned. When the desired amount of cleaning has taken place, the drill string is rotated which forces the bridge plug 12 to shorten and thus expand in order to block the well, in a conventional manner. In order to achieve this setting, the lower part of the bridge plug has to turn freely to allow the tool to shorten and expand. The casing brush 20 attached to the bottom of the bridge plug 12 would otherwise have a tendency to hold the centre of the bridge plug 12 from turning due to the friction of the brush bristles 24 against the casing wall. The torque-free swivel adapter 18 solves this problem by allowing torque-free attachment of the casing brush 20 to the lower part of the bridge plug.

With the bridge plug 12 firmly in position against the casing wall, the perforating gun 36 can be detonated. During detonation, the lower, outer tube 38a of the extension tube assembly 38 moves upwardly with respect

to the upper, inner tube 38b. The relative movement between the two is damped by the resilient damper rings 52a to 52e, and much of the upward force is thereby absorbed and dissipated, and is not transferred to the bridge plug 12.

5 Figs. 4 and 5 show a modification to the perforating drill string assembly of Figs. 1 to 3. The assembly comprises many of the components of the assembly of Figs. 1 to 3, but differs in that the extension tube 38 of Figs. 1 to 3 is replaced with a damping assembly 60 as shown in Figs. 4 and 5. The damping assembly, in use, is secured to  
10 the body 22 of a well casing brush 20 and to a tubular drill string explosive charge (a perforating gun) 36, as will be explained.

As shown in Figs. 4 and 5, the damping assembly 60 comprises a cylindrical tubular metal casing 62 which is closed off at its upper end by a planar end wall 64 welded to the upper end of the metal casing 62. The  
15 diameter of the casing is chosen so that it can be lowered into a typical well casing 10, with clearance around its periphery. A cylindrical connecting rod 65 extends perpendicularly from the upper surface of the end wall 64. The upper end of the connecting rod is screw-threaded (shown at S), by means of which in use it is connected to the threaded  
20 recess 42 of the body 22 of a well casing brush 20.

First and second pistons 66, 68 are slidably disposed within the well casing 62 and are kept at a constant spacing from one another by a first longitudinally extending central connecting rod 70 rigidly connected (e.g. by welding) to the lower face of the upper piston 66 and the upper face of

the lower piston 68. A second longitudinally extending connecting rod 72 is rigidly connected (e.g. by welding) to the lower face of the lower piston and extends out of the open lower end of the casing 62. The lower extremity of the connecting rod 72 is screw-threaded (not visible in the drawings) by means of which it is connected in use to the upper end of a conventional tubular drill string explosive charge 36.

The pistons 66, 68 are prevented from falling out of the open lower end of the casing 62 by engagement of the periphery of the lower face of the upper piston 66 with an inwardly-directed annular shoulder 74 welded to the inner surface of the casing 62, as shown in Fig. 4, which thereby defines the lowermost position of the pistons 66, 68. The first connecting rod 70 can pass through the inwardly-directed annular shoulder 74 but a plurality of identical, compressible, resiliently deformable silicone rubber rings 76 are retained within the casing 62 between the upper face of the lower piston 68 and the annular shoulder 74.

Two identical, diametrically opposed fluid inlet ports 78 are formed in the wall of the casing 62, immediately above the level of the upper face of the upper piston 66, when the upper piston is in its lowermost position (as shown in Fig. 4). Four identical exhaust ports 80 are also provided in the wall of the casing 62, just below the upper end of the casing. The exhaust ports 80 at the same level and are equally spaced around the casing, i.e. at 90° intervals. As seen in Figs. 4 and 5, the longitudinal axis of each of the exhaust ports 80 is inclined at 45° to the longitudinal axis (and the radial axis) of the casing.

The drill casing will be full of liquid (e.g. water, drilling mud, hydrocarbons or a mixture of these) which will inevitably enter the casing 62, into the space above the upper piston 66, primarily via the fluid inlet ports 78. Fluid may also enter the casing via the upper ports 80, but  
5 during entry of the fluid into the casing, the upper ports 80 will mainly allow the escape of air displaced by the entering fluid. As a consequence, once the casing is positioned within a well, the region of the casing above the upper piston 66 will be full of fluid.

In use, the tubular drill string explosive charge 36 is screw-  
10 threadedly connected to the lower connecting rod 72 and the upper connecting rod 65 which extends from the end wall 64 is screw-threadedly connected into the recess 42 of the body 22 of a well casing brush 20. The well casing brush is in turn connected to a setting tool 14 via an adapter 18, as in the embodiment of Figs. 1 to 3.

15 The entire perforating drill string assembly is then lowered down a well by attaching the setting tool to a conventional drill string (not shown). When the desired setting depth has been reached, the assembly may be moved up and down and cleaning fluid may be injected from the drilling brush 20 into the area to be cleaned. When the desired amount of  
20 cleaning has taken place, the drill string is rotated which forces the bridge plug 12 to shorten and thus expand in order to block the well, in a conventional manner. In order to achieve this setting, the lower part of the bridge plug has to turn freely to allow the tool to shorten and expand. The casing brush 20 attached to the bottom of the bridge plug 12 would

otherwise have a tendency to hold the centre of the bridge plug 12 from turning due to the friction of the brush bristles 24 against the casing wall. The torque-free swivel adapter 18 solves this problem by allowing torque-free attachment of the casing brush 20 to the lower part of the bridge plug.

5           With the bridge plug firmly seated against the wall of the casing 10, the explosive charge 36 is detonated. Detonation of the charge 36 produces a large volume of gas extremely quickly and the consequent increase in pressure forces the lower piston 68 upwardly within the casing 62. As the piston 68 moves upwardly, the silicone rubber rings 76 located  
10   between the upper surface of the lower piston 68 and the annular shoulder 74 are compressed, as shown in Fig. 5, which absorbs some of the energy produced by the detonation and reduces the resultant force on the bridge plug 12.

          Since the upper and lower pistons 66, 68 are connected, upward  
15   movement of the lower piston 68 also results in upward movement of the upper piston 66. As the upper piston 66 passes the uppermost edge of the inlet ports 78, fluid can no longer exit the casing 62 via the ports 78 but can only exit via the exhaust ports 80 towards the upper end of the casing 62. As the piston 66 moves upwardly, fluid in the casing 62 above the  
20   upper piston 66 is forced out of the casing through the ports 80, which produces a damping of the piston, thereby absorbing additional energy from the detonation and further reducing the resultant force on the bridge plug 12.

Further variations are shown in Figs. 6 and 7.

In Fig. 6, the volume of the casing 62 above the upper piston 66 is pre-filled with fluid. The lower inlet ports 78 are closed off with conventional burst discs 84 which will rupture when the external pressure exceeds a threshold value, and will rupture upon detonation of the explosive charge  
5 36. The upper ports 80 are also closed off with burst discs 86 (Fig. 6) but alternatively may be closed off with check valves 88 (Fig. 7). The construction and operation of the Fig. 6 and Fig. 7 configurations are otherwise identical to those of Figs. 5 and 6. The invention is not restricted to the details of the foregoing embodiments.

10 For example, a plurality of extension tubes 38 (Figs. 1 to 3) or damping assemblies 60 (Figs. 4 to 7), or a combination of these, may be connected in series in order to increase the damping effect.

CLAIMS

1. A perforating drill string assembly comprising a bridge plug, a casing brush or scraper connected to the lower end of the bridge plug and an explosive perforating gun connected to the casing brush or scraper.

5        2. A perforating drill string assembly as claimed in claim 1, further comprising elongate connecting means, extending between, and connecting, the casing brush or scraper and the perforating gun.

3. A perforating drill string as claimed in claim 2, wherein the elongate connecting means comprises damping means.

10       4. A perforating drill string assembly as claimed in claim 3, wherein the length of the elongate connecting means is adjustable.

5. A perforating drill string assembly as claimed in claim 4, wherein the elongate connecting means is adapted to be compressed on detonation of the perforating gun by the resultant upward well fluid  
15       pressure surge caused by said detonation.

6. A perforating drill string assembly as claimed in any of claims 2 to 5, wherein the elongate connecting means comprises first and second elongate members slidably mounted with respect to each other, each of the first and second elongate members being connected to a respective  
20       one of the casing brush or scraper and the perforating gun.

7. A perforating drill string assembly as claimed in claim 6, wherein one of the first and second elongate members is slidably disposed within the other of the first and second elongate members.



8. A perforating drill string assembly as claimed in claim 6 or claim 7, further comprising damping means for resisting relative displacement of the first and second elongate members upon detonation of the perforating gun.

5        9. A perforating drill string assembly as claimed in claim 8, wherein the damping means comprises a deformable member which is deformed when the elongate connecting means is compressed.

10       10. A perforating drill string assembly as claimed in claim 9, wherein the damping means comprises a plurality of deformable members which are deformed when the elongate connecting means is compressed.

11. A perforating drill string assembly as claimed in claim 10, comprising a stack of deformable members.

12. A perforating drill string assembly as claimed in claim 9 or claim 10, wherein the or each deformable member is annular.

15       13. A perforating drill string assembly as claimed in any of claims 6 to 12, further comprising means for limiting compression of the elongate connecting means on detonation of the perforating gun.

20       14. A perforating drill string assembly as claimed in claim 13, wherein the means for limiting compression comprises one or more grooves in one of the first and second elongate members which receive a projection secured to the other of the first and second elongate members.

15. A perforating drill string as claimed in any of claims 2 to 13, wherein the elongate connecting means comprises an elongate casing and piston means slidably disposed in the elongate casing, each of the

elongate casing and the piston means being connected to a respective one of the casing brush or scraper and the explosive perforating gun.

16. A perforating drill string as claimed in claim 15, further comprising one or more deformable members which are formed when the  
5 piston means is displaced.

17. A perforating drill string as claimed in claim 16, wherein the one or more deformable members are located between the piston means and a portion foxed with respect to the casing.

18. A perforating drill string as claimed in claim 17, wherein the or  
10 each deformable member is annular.

19. A perforating drill string as claimed in any of claims 15 to 18, wherein the casing comprises one or more fluid outlet ports.

20. A perforating drill string as claimed in claim 19, wherein the or each fluid outlet port is mounted at or towards an upper end of the casing.

15 21. A perforating drill string as claimed in claim 19 or claim 20, wherein the axis of the or each outlet port is inclined to the longitudinal direction of the casing.

22. A perforating drill string as claimed in any of claims 19 to 21, wherein the or each fluid outlet port comprises means for preventing  
20 exhaust of fluid at pressures below a threshold value.

23. A perforating drill string as claimed in claim 22, wherein the means for preventing exhaust of fluid comprises a burst disc.

24. A perforating drill string as claimed in claim 22 or claim 23, wherein the means for preventing exhaust of fluid comprises a non-return valve.

25. A perforating drill string as claimed in any of claims 15 to 24,  
5 wherein the casing comprises one or more fluid inlet valves.

26. A perforating drill string as claimed in claim 25, wherein the or each fluid inlet valve is closed by movement of the piston means.

27. A perforating drill string assembly substantially as herein described with reference to, and as illustrated in, the accompanying  
10 drawings.

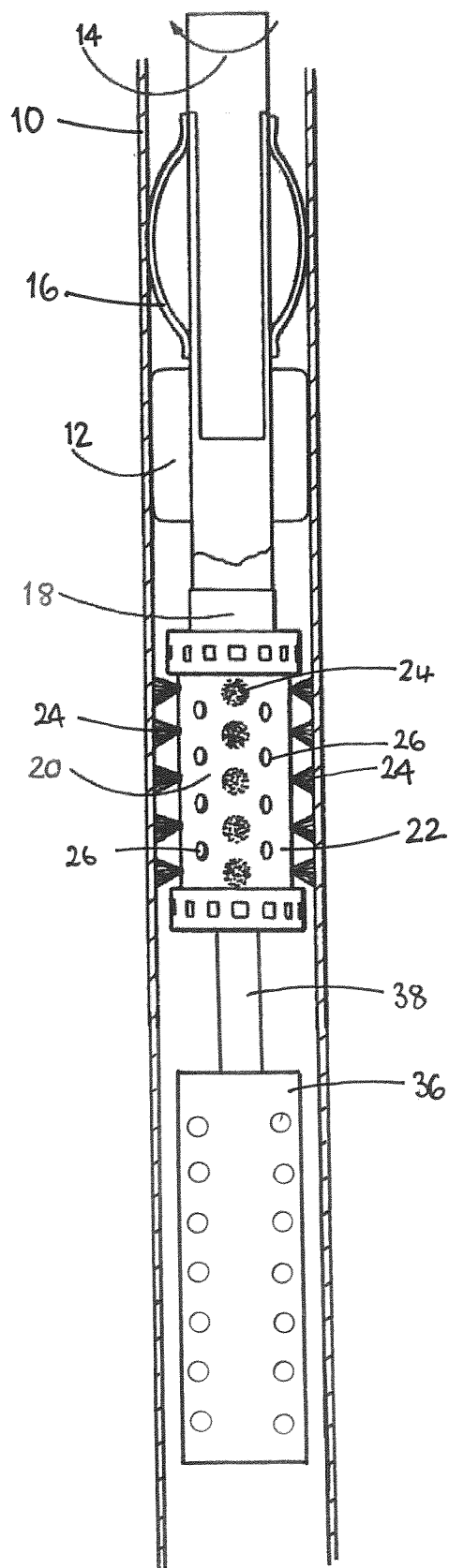


Fig. 1

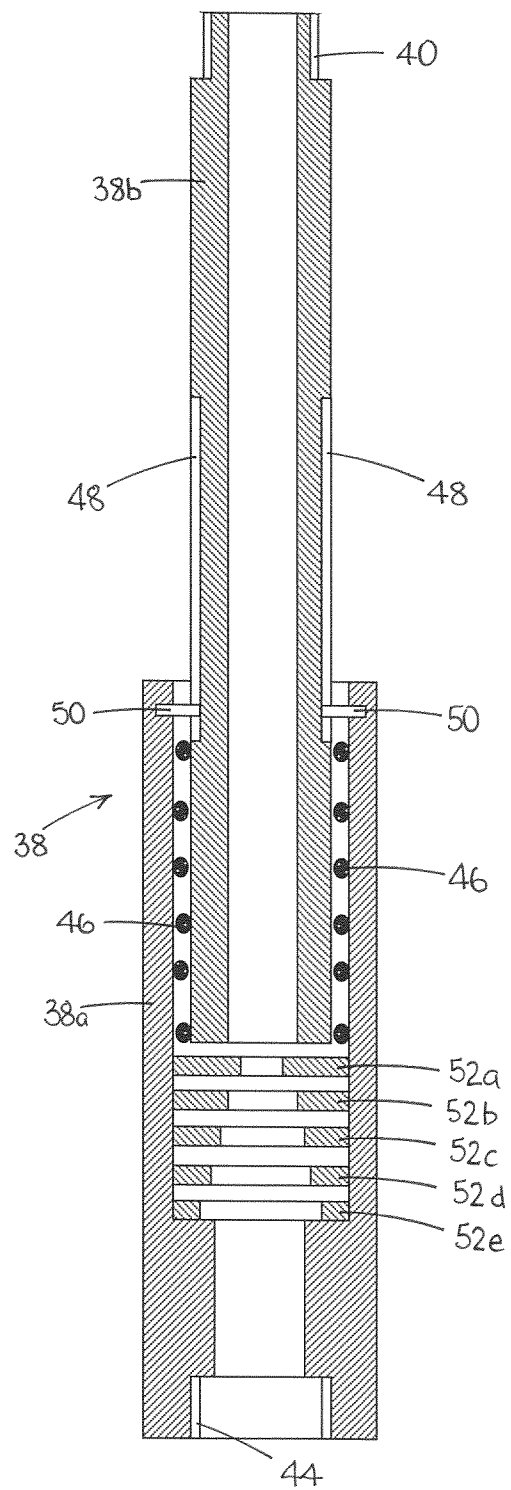


Fig. 2

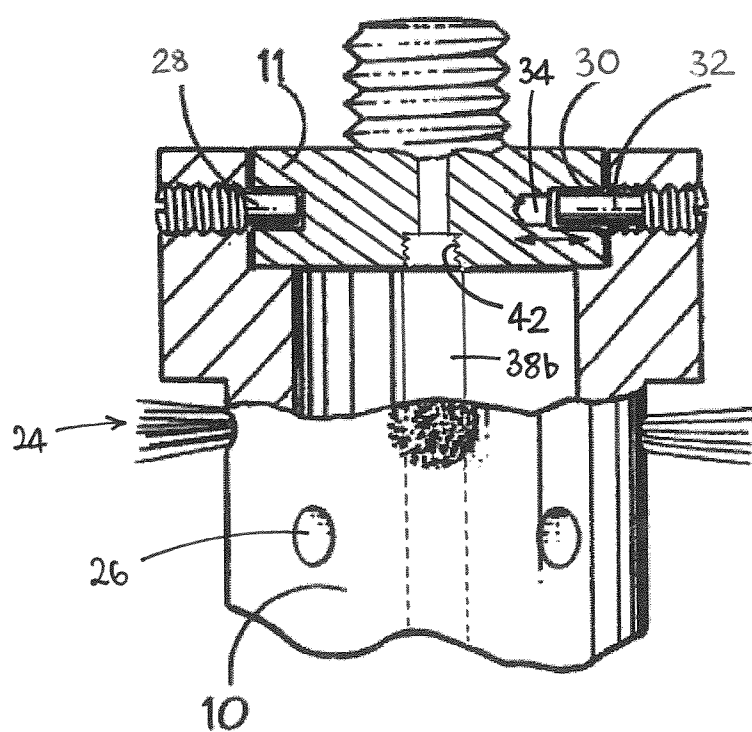


Fig. 3

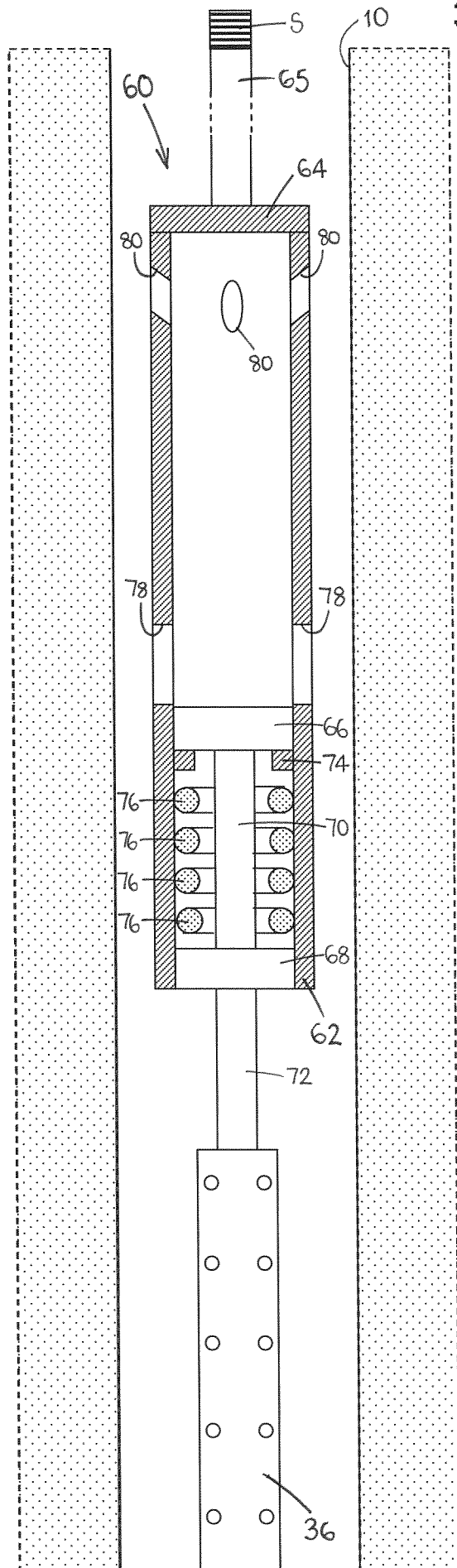


Fig. 4

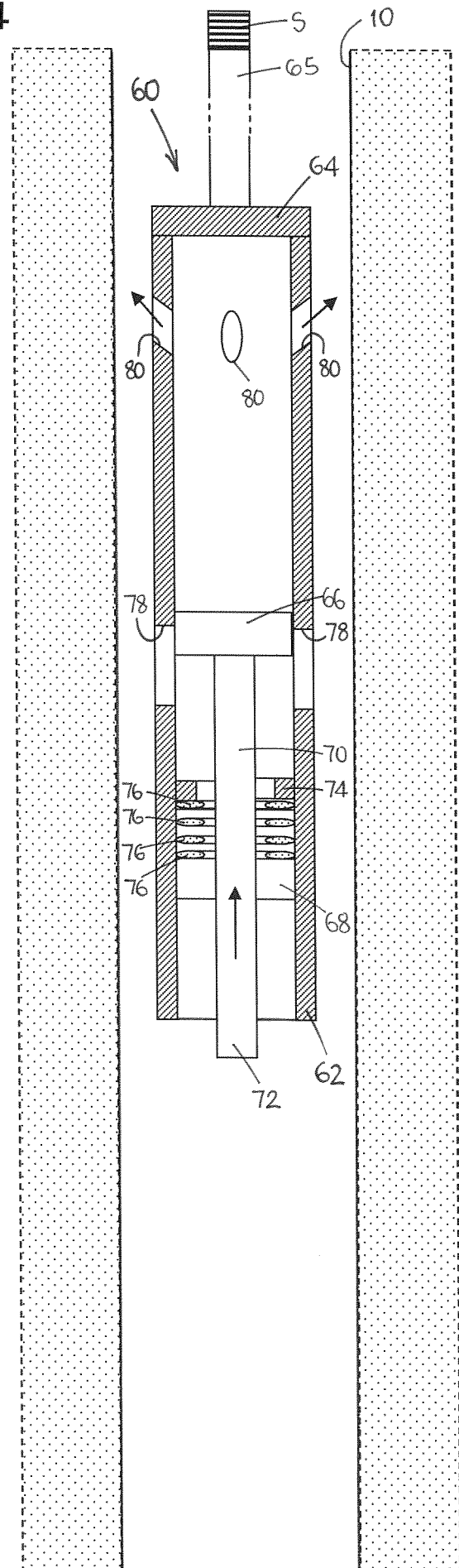


Fig. 5

4/4

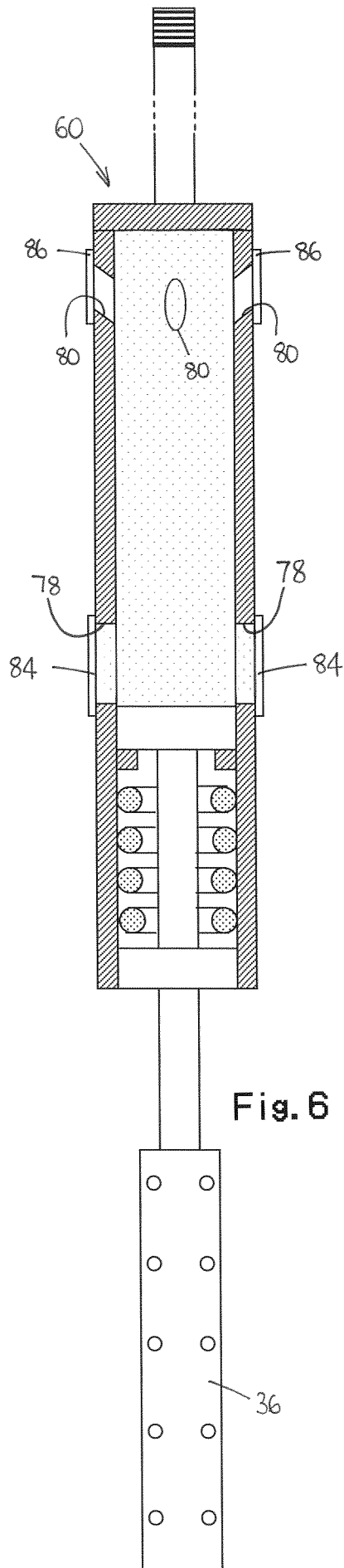


Fig. 6

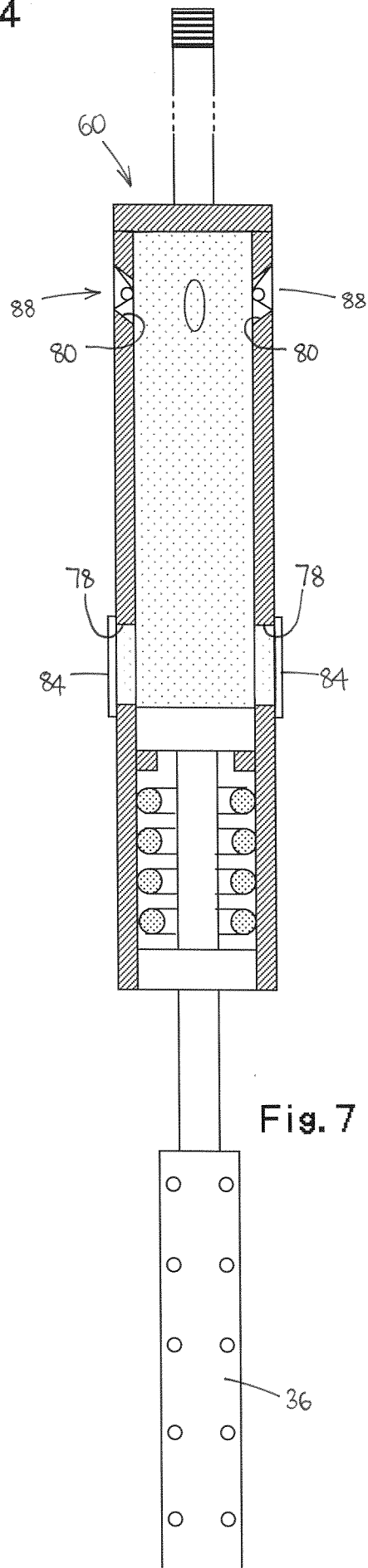


Fig. 7