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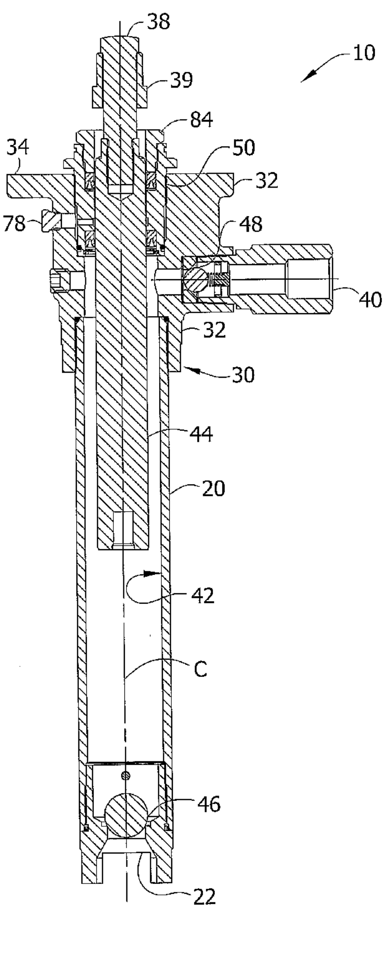
(54) Title: LOW-FRICTION RECIPROCATING PUMP



(57) Abstract: A reciprocating pump for pumping a fluid, especially for pumping a fluid such as UV ink which is subject to solidification when exposed to frictional forces. The pump has an internal displacement chamber with an inlet, and outlet, and a plunger which is reciprocally movable in the chamber. The plunger reciprocates through an axial passage in the housing at one end of the chamber, the passage being sized to receive the plunger with a clearance fit. First and second seals are positioned in the axial passage. Each seal is annular in shape and extends between the plunger and housing in sealing contact therewith. The pump housing is free from a bearing which contacts the plunger or guides its motion, such that the sealing contacts between the plunger and seals are the only contacts of the plunger in the housing.

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LOW-FRICTION RECIPROCATING PUMP

Background of the Invention

[0001] This invention relates to reciprocating pumps for pumping fluids, and more particularly to a pump which lengthens the operational life of the pump by reducing the frictional forces expended on the fluid being pumped. The pump is described primarily herein for application in pumping a fluid which is subject to solidification when exposed to frictional forces. However, it is understood that the pump and seal assembly may be applied to efficiently pump any type of fluid.

[0002] Ink that is cured with ultraviolet (UV) energy has widespread use in the printing and graphic display industries. That type of ink is highly viscous and has a unique chemistry which requires special handling and pumping needs. Its material composition includes a monomer, instead of a solvent as in conventional inks, such that it solidifies when irradiated. Unfortunately, UV ink is also sensitive to mechanical shear stress (i.e., friction) which produces heat and initiates solidification of the ink. Conventional displacement pumps expose UV ink to substantial friction as it is pumped. Consequently, solidified polymers form and accumulate in the pump which cause the pump to bind and ultimately fail. Of particular concern are gaps between close-fitting parts which have relative movement. For example, a conventional pump has a reciprocal plunger received in a stationary bearing or sleeve for guiding movement and preventing "wobble" of the plunger as it reciprocates. The close-fit sliding motion produces localized regions of high friction at small gaps between the plunger and the bearing or sleeve. UV ink which reaches these gaps is prone to solidify. Aggravating this problem is that the plunger assembly must be sealed to prevent leaks.

Summary of the Invention

[0003] Among the several objects and features of the present invention may be noted the provision of a fluid pump which exerts less frictional force on the fluid being pumped; the provision of such a pump which effectively pumps a highly viscous fluid including UV ink; the provision of such a pump which is sealed to prevent leakage of fluid; and the provision of such a pump which is efficient and durable in use and cost-efficient to construct.

[0004] In general, a reciprocating pump of the present invention is for pumping a fluid. The pump comprises a pump housing having an internal displacement chamber with an inlet, and outlet, a longitudinal axis, and opposite ends. A plunger is reciprocally movable in the chamber along the axis. An axial passage is in the housing at one end of the chamber through which the plunger axially reciprocates. First and second annular seals in the axial passage are generally co-axial with the passage and spaced from one another longitudinally of the passage. Each seal is sized for sealing contact with the plunger. The pump housing is free from a bearing which contacts the plunger or guides its motion. The plunger is free from direct engagement with the housing, and the sealing contacts of the plunger with the first and second seals are the only contacts of the plunger in the housing.

[0005] In another aspect, a reciprocating pump of this invention is for pumping a fluid. The pump includes a pump housing having an internal displacement chamber with an inlet, and outlet, a longitudinal axis, and opposite ends. A plunger is reciprocally movable in the chamber along the axis. An axial passage is in the housing at one end of the chamber through which the plunger axially reciprocates, the axial passage having at least a portion which defines a minimum clearance region for the plunger in the housing. The minimum clearance region is sized to receive the plunger therethrough with a clearance fit. The plunger has an outer diameter D1, the minimum clearance region has an internal diameter D2, and D2 is larger than D1 by at least about 0.015 inch.

[0006] In yet a further aspect, a reciprocating pump of this invention is for pumping a fluid. The pump comprises a pump housing having an internal displacement chamber with an inlet, and outlet, a longitudinal axis, and opposite ends. A plunger is reciprocally movable in the chamber along the axis. An axial passage is in the housing at one end of the chamber through which the plunger axially reciprocates, the axial passage having at least a portion which defines a minimum clearance region for the plunger in the housing. The minimum clearance region of the axial passage has an axial length L1 which is less than 1.0 inch.

[0007] In still another aspect, a reciprocating pump according to the present invention is for pumping a fluid. The pump comprises a pump housing having an internal displacement chamber with an inlet, and outlet, a longitudinal axis, and opposite ends. The housing includes a pump head, a cylinder attached to the head, and a gland attached to the head generally opposite the cylinder. A plunger is reciprocally movable in the chamber along the axis. An axial passage is in the gland through which the plunger axially reciprocates. First and second annular seals in the axial passage are generally co-axial with the passage and spaced from one another longitudinally of the passage. Each seal is sized for sealing contact with the plunger and has a generally U-shaped cross-section with two opposing legs in respective sealing contact with the plunger and housing. The two legs of each seal are asymmetrical. The axial passage comprises an intermediate section between the seals which is sized to receive the plunger therethrough with a clearance fit. Internal shoulders are at opposite longitudinal ends of the intermediate section. Each of the seals is positioned adjacent a respective shoulder in the axial passage, at least one of the seals being retained by a threaded nut. The pump housing is free from a bearing which contacts the plunger or guides its motion. The plunger is free from direct engagement with the housing, and the sealing contacts of the plunger with the first and second seals are the only contacts of the plunger in the housing.

[0008] Other objects and features of the present invention will be in part apparent and in part pointed out hereinafter.

Brief Description of the Drawings

[0009] FIG. 1 is a schematic of a system for pumping fluid with a pump of this invention;

[0010] FIG. 2 is a perspective of the pump;

[0011] FIG. 3 is a vertical section of the pump;

[0012] FIG. 4 is an enlarged fragment of Fig. 3;

[0013] FIG. 5 is a vertical section of a gland of the pump; and

[0014] FIG. 6 is a perspective of the gland.

[0015] Corresponding reference characters indicate corresponding parts throughout the views of the drawings.

Detailed Description of the Preferred Embodiment

[0016] Referring now to the drawings and in particular to Fig. 1, a pump according to the present invention for delivering fluid to a device requiring fluid is indicated generally at 10. The pump 10 may be used, for example, in pumping ink from a supply container 12 (e.g., a drum) to fountains of a printing press 14. In one embodiment, the pump 10 is supported upon a follower plate 16 near the upper surface of fluid in the container 12. The plate 16 and pump 10 move downward in the container 12 as fluid is removed and the elevation of the upper surface of fluid is lowered. The pump 10 has a cylinder 20 which, in one embodiment, is oriented vertically with its lower end submerged in fluid of the container 12. The lower end of the cylinder has an opening comprising an inlet 22 for receiving fluid. A motor 24 is positioned above the pump for driving the pump, and a transverse outlet tube 26 extends away from the pump for delivery of fluid to the printing press 14. It is understood that the pump 10 can have other arrangements or orientations without departing from the scope of this invention.

[0017] As shown in Fig. 2, the pump 10 comprises a housing, indicated generally at 30, including a head 32 which is generally cylindric in shape and has a mounting flange 34. The cylinder 20 extends from the head 32 in longitudinal alignment with the head. The flange 34 has bores 36 for receiving tie rods (not shown) to fasten the head 32 to the motor 24. A connector 38 and coupling nut 39 are provided for operative connection of the pump 10 to a powered drive shaft (not shown) of the motor 24. An outlet 40 extends from the head 32 for connection to the outlet tube 26.

[0018] Referring to Fig. 3, the head 32 and cylinder 20 define an internal displacement chamber, indicated generally at 42, with a longitudinal axis C. A plunger 44 is reciprocally movable in the chamber 42 along the axis. In one embodiment, the plunger 44 is cylindric, having an outer (radial) diameter D1. In one embodiment, the external surface of the plunger 44 includes a material which is smooth and inhibits friction with fluid as it moves therepast. An exemplary surface material is a series of nickel-based alloy coatings deposited according to MAGNAPLATE HMF®, a process which is proprietary to the General Magnaplate Corporation having offices in Linden, New Jersey. The pump 10 has a first check valve 46 at the inlet 22 for permitting one-directional flow of fluid into the chamber 42. A second check valve 48 at the outlet 40 allows one-directional flow of fluid out from the chamber 42. In one embodiment, the first and second check valves 46, 48 have conventional round balls and corresponding seats. That type of valve closes quickly and reduces the possibility of small openings or gaps which would expose the fluid to shear stress as it passes through a partially closed valve.

[0019] The pump 10 is known to those skilled in the art as a "single-acting" type pump having a pumping cycle which discharges fluid only during a stroke of the plunger 44 in one direction. During an upstroke, the plunger 44 moves outward (up in Fig. 3), the first check valve 46 is open, and fluid is drawn through the inlet 22 into the chamber 42. The second check valve 48 is closed and blocks any discharge. During a downstroke, the plunger 44 moves inward, the first check valve 46 is closed, and the plunger displaces fluid in the chamber 42 such that it opens the second valve 48. Fluid is then discharged through the outlet 40 while the first check valve 46 remains closed. Other configurations of the pump 10 do not depart from the scope of this invention. In particular, it is understood that the pump could be a "double-acting" pump wherein fluid is forced between two separate chambers in the pump, and fluid is discharged during a pumping cycle on both an upstroke and a downstroke.

[0020] The pump housing 30 includes a gland 50 secured (e.g., threaded) in the head 32 generally opposite the cylinder 20. The gland 50 defines an axial passage, indicated generally at 52, at one end (e.g., the upper end) of the chamber 42 through which the plunger 44 axially reciprocates. The gland 50 is shown in isolated detail in Figs. 5 and 6. The gland has a generally cylindric external surface which includes screw threads 54 on an upper portion thereof. The upper portion is formed with a hexagonal gripping flange 56. An annular groove 58 extends around a lower portion of the external surface of the gland 50 for receiving an O-ring seal 60, shown in Fig. 4, to prevent leaks between the gland and head 32.

[0021] In the embodiment shown in Fig. 5, the axial passage 52 comprises an outer (upper) section 62 defined by a first generally cylindric surface, an intermediate section 64 inward of (below) the outer section defined by a second generally cylindric surface, and an inner (lower) section 66 defined by a third generally cylindric surface. As shown, the intermediate section 64 has an internal diameter D2; the upper section 62 has an internal diameter D3 greater than D2; and the lower section 66 has an internal diameter D4 greater than D2, with D3 and D4 being approximately the same in the illustrated embodiment. As shown in Fig. 5 and discussed more fully below, the intermediate section 64 of the axial passage 52 has an axial length designated L1, and the upper and lower sections 62, 66 have axial lengths designated L2 and L3, respectively. Due to the relative sizing of the internal diameters of the upper, intermediate and lower sections of the passage, the plunger 44 as received in the gland 50 is spaced relatively closer in a radial direction to the generally cylindric surface of the intermediate section 64 than to the surfaces of the upper and lower sections 62, 66. The changes in the internal diameter of the axial passage 52 form an outer (upper) flat annular shoulder 68 at the juncture of the upper and intermediate sections 62, 64 of the axial passage. Similarly, an inner (lower) flat annular shoulder 70 is formed at the juncture of the lower and intermediate sections 66, 64 of the axial passage. It is understood that the gland 50 may have continuous, gradual changes in diameter, a different arrangement of sections, a fewer or greater number of sections (including only one section of uniform diameter), and/or may be integrally formed with the head without departing from the scope of this invention.

[0022] An annular groove 72 extends around the intermediate section 64 of the axial passage 52 and communicates with a transverse drain bore 74 for draining fluid which may reach the axial passage. The bore 74 in turn communicates with a bore 76 (Fig. 4) in the head 32 of pump 10. A plug 78 is threadably received in the bore 76 of the head for closing the drain.

[0023] Referring to Fig. 4, first and second annular seals 80, 82 are positioned in the axial passage 52 generally co-axial with the passage and spaced from one another longitudinally of the passage. The first (upper) seal 80 is positioned in the upper section 62 of the axial passage adjacent the upper shoulder 68, and the second (lower) seal 82 is positioned in the lower section 66 of the passage adjacent the lower shoulder 70. Each seal surrounds the plunger 44 and is sized for sealing contact therewith. The upper seal 80 is removably retained in the upper section 62 of the axial passage adjacent the upper shoulder by a packing nut 84 threaded down in the gland 50. The lower seal 82 is removably retained in the lower section 66 of the axial passage by a retaining ring 85 received in an internal groove of the gland. A flat washer 86 is disposed between the ring 85 and the lower seal 82 to prevent damage to the seal. In one embodiment, each of the upper and lower seals 80, 82 is a cup seal having a generally U-shaped cross-sectional profile with a rectangular base and two opposing legs extending from the base defining a recess between the legs. The opposing legs are asymmetrical and configured to remain in sealing contact with respective surfaces of the gland 50 and plunger 44. A tip 88 of the radially inner leg has a chamfered edge which comprises a wiping surface in contact with the plunger 44. The seals 80, 82 are oriented with the legs pointed toward the chamber 42 (downward in Fig. 4) for effective sealing, especially during upstrokes of the plunger 44 when fluid on the surface of the plunger tends to move with the plunger outward from the chamber.

[0024] In one embodiment, the first and second seals 80, 82 are substantially identical in size, material, and configuration. However, it is understood that the seals can vary without departing from the scope of this invention. The seals are made of a suitable material which is stiff, has high mechanical strength, flexibility, and resiliency over a range of pressures. An exemplary material is an elastomer such as polyurethane having a durometer hardness (Shore A scale) within the range between 87 and 97, and more preferably having a durometer hardness about 92. In practice, an effective and commercially available seal is a Disogrin® asymmetrical piston U-cup seal manufactured by Simrit®, having offices in Plymouth, Michigan.

[0025] To reduce friction, particularly resulting from shear forces exerted on the fluid being pumped, the outer diameter D1 of the plunger 44 is sized for a relatively loose clearance fit within the axial passage 52. In this regard, the internal diameter D2 of the narrowest section of the axial passage 52 (the intermediate section 64 of the passage in the illustrated embodiment) is significantly greater than the outer diameter D1 of the plunger 44, defining a clearance or gap G around the plunger as indicated on Fig. 4. In one embodiment, D2 is larger than D1 by at least about 0.010 inches, and more preferably at least about 0.016 inches. This dimensional difference provides a respective average gap G on each side of the plunger of 0.005 and more preferably 0.008 inches. In practice, that gap is of sufficient width that the shear stress on the fluid therein is insufficient to produce solidification of UV ink. In one embodiment, D1 is 1.164 inches and D2 is 1.180 inches, providing an average gap G of 0.008 inch on each side of the plunger and a diameter ratio of D2/D1 greater than 1.01.

[0026] The relatively loose fit does not produce greater instability or "wobble" in the motion of the plunger 44 because of the seal configuration. The two seals 80, 82 function as bearings to guide and stabilize movement of the plunger 44. The spaced-apart positions of the seals in the upper and lower sections 62, 66 of the axial passage, adjacent the narrowest section 64, provide an effective combination for stabilizing the plunger 44. This arrangement avoids the need for a sleeve or bearing which would result in increased friction. Further, if any UV ink fluid does solidify due to friction at the wiping surfaces 88 of the first and second seals 80, 82, its adverse effect is minimized by the relatively short axial length of these wiping surfaces which limits solidified ink to a narrow line at each wiping surface 88.

[0027] Friction is further inhibited by the relatively short longitudinal length of the narrowest section of the axial passage 52, which is the intermediate section 64 in the illustrated embodiment. In one embodiment, the length L1 of this section is preferably within a range between about 0.4 and 1.0 inches, and more preferably only about 0.9 inches. Thus, to the extent any fluid leaks into this area, the shearing forces exerted on fluid are kept to a minimum. In practice, a length

L1 is about 0.92 inches, providing a ratio of L1 to plunger diameter D1 (L1/D1) of about 0.79. That length L1 includes the length of the drain groove 72 which is wider than other portions of the intermediate section 64. When the length of the drain groove 72 is subtracted, an effective length L1 is about 0.73 inches, providing an effective ratio (L1/D1) of about 0.63.

[0028] As illustrated in Fig. 5, L1 is less than L2 but greater than L3. By way of example, L1, L2 and L3 may be 0.92, 1.06, and 0.58 inches, respectively. These dimensions may vary.

[0029] In addition, friction is further reduced by the lack of valves or shut-off control in the outlet tube 26 which delivers fluid from the outlet 40 of the pump chamber to the device 14 requiring fluid. As a result, the fluid is subjected to only minimal shearing forces and thus less friction, thereby reducing any solidification of the fluid for more effective pump operation and longer pump life.

[0030] In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

[0031] When introducing elements of the present invention or the preferred embodiment(s) thereof, the articles "a", "an", "the" and "said" are intended to mean that there are one or more of the elements. The terms "comprising", "including" and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements.

[0032] As various changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description as shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

WHAT IS CLAIMED IS:

1. A reciprocating pump for pumping a fluid, comprising:

a pump housing having an internal displacement chamber with an inlet, and outlet, a longitudinal axis, and opposite ends;

a plunger which is reciprocally movable in the chamber along said axis;

an axial passage in the housing at one end of the chamber through which the plunger axially reciprocates; and

first and second annular seals in the axial passage generally co-axial with the passage and spaced from one another longitudinally of the passage, each seal being sized for sealing contact with the plunger;

wherein the pump housing is free from a bearing which contacts the plunger or guides its motion, wherein the plunger is free from direct engagement with the housing, and wherein said sealing contacts of the plunger with the first and second seals are the only contacts of the plunger in the housing.

2. A reciprocating pump as set forth in claim 1 wherein the axial passage comprises an intermediate section between said seals which is sized to receive the plunger therethrough with a clearance fit.

3. A reciprocating pump as set forth in claim 2 wherein said intermediate section of the axial passage defines a minimum clearance region for the plunger in the housing.

4. A reciprocating pump as set forth in claim 2 wherein the plunger has an outer diameter D1, the intermediate section of the axial passage has an internal diameter D2, and a ratio of D2 to D1 is greater than 1.01.

5. A reciprocating pump as set forth in claim 2 wherein the plunger has an outer diameter D1, the intermediate section of the axial passage has an axial length L1, and a ratio of L1 to D1 is within a range between 0.5 and 1.0.

6. A reciprocating pump as set forth in claim 2 wherein the axial passage has internal shoulders at opposite longitudinal ends of said intermediate section, and wherein each of said seals is positioned adjacent a respective shoulder in the axial passage.

7. A reciprocating pump as set forth in claim 1 further comprising a threaded nut received in the housing, and wherein the axial passage has an internal shoulder therein, one of said seals being retained at a position adjacent said internal shoulder by the threaded nut.

8. A reciprocating pump as set forth in claim 1 wherein each seal has a generally U-shaped cross-section with two opposing legs in respective sealing contact with the plunger and housing.

9. A reciprocating pump as set forth in claim 8 wherein said two legs of each seal are asymmetrical.

10. A reciprocating pump as set forth in claim 1 wherein the housing comprises a pump head, a cylinder attached to the head, and a gland attached to the head generally opposite the cylinder, and wherein said axial passage is disposed in the gland.

11. A reciprocating pump as set forth in claim 1 wherein the pump is a single-acting pump which, during an upstroke, receives fluid through the inlet into the chamber without simultaneous discharge through the outlet, and which, during a downstroke, discharges fluid from the chamber through the outlet.

12. A reciprocating pump as set forth in claim 1 further comprising drain comprising an annular groove in the axial passage for draining fluid which is located between the first and second seals.

13. A reciprocating pump as set forth in claim 1 in combination with a container for supplying fluid to the inlet of the chamber, and a tube for delivering fluid from the outlet of the chamber to a device requiring fluid, and wherein the tube is free from valves between the outlet and the device.

FIG. 1

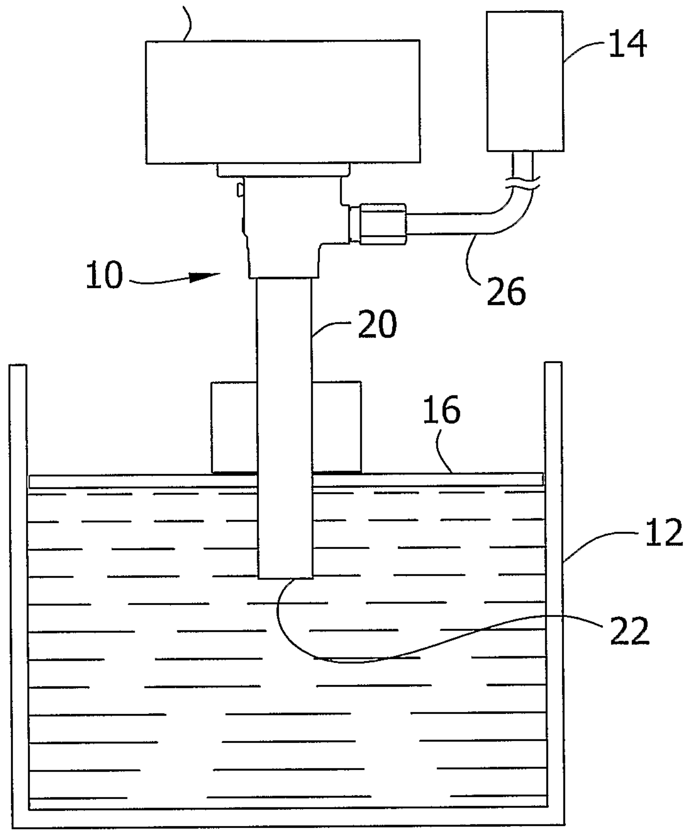

FIG. 2

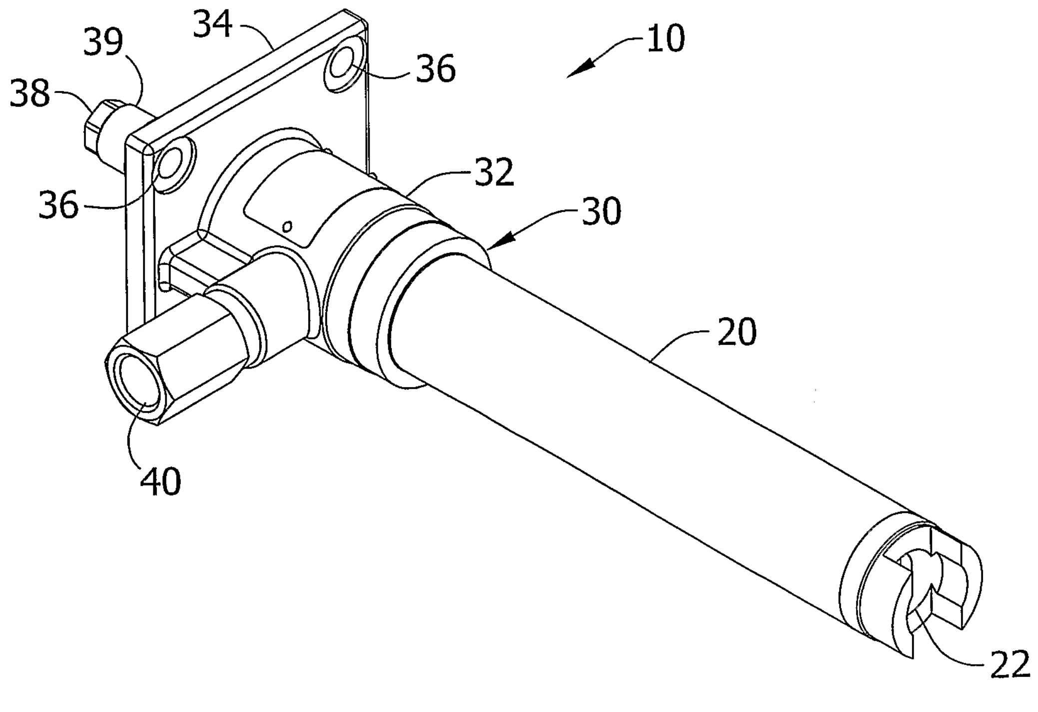

FIG. 3

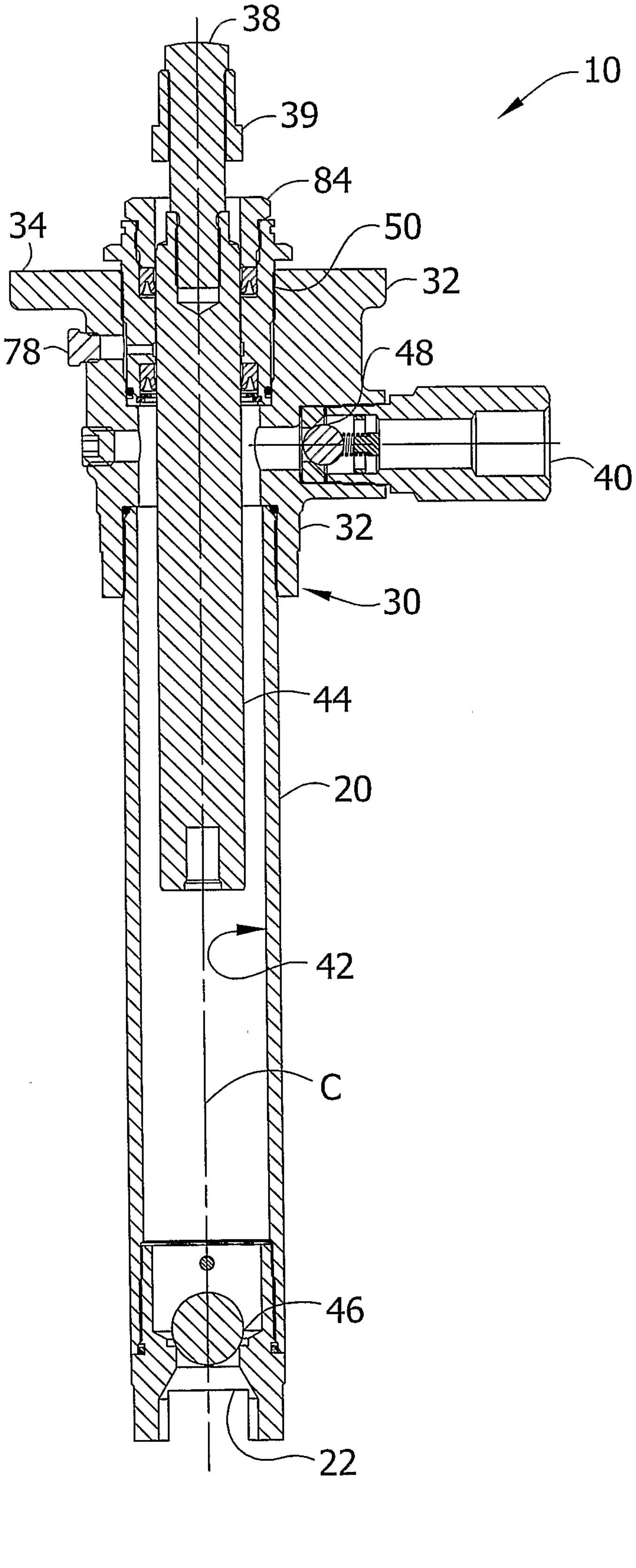

FIG. 4

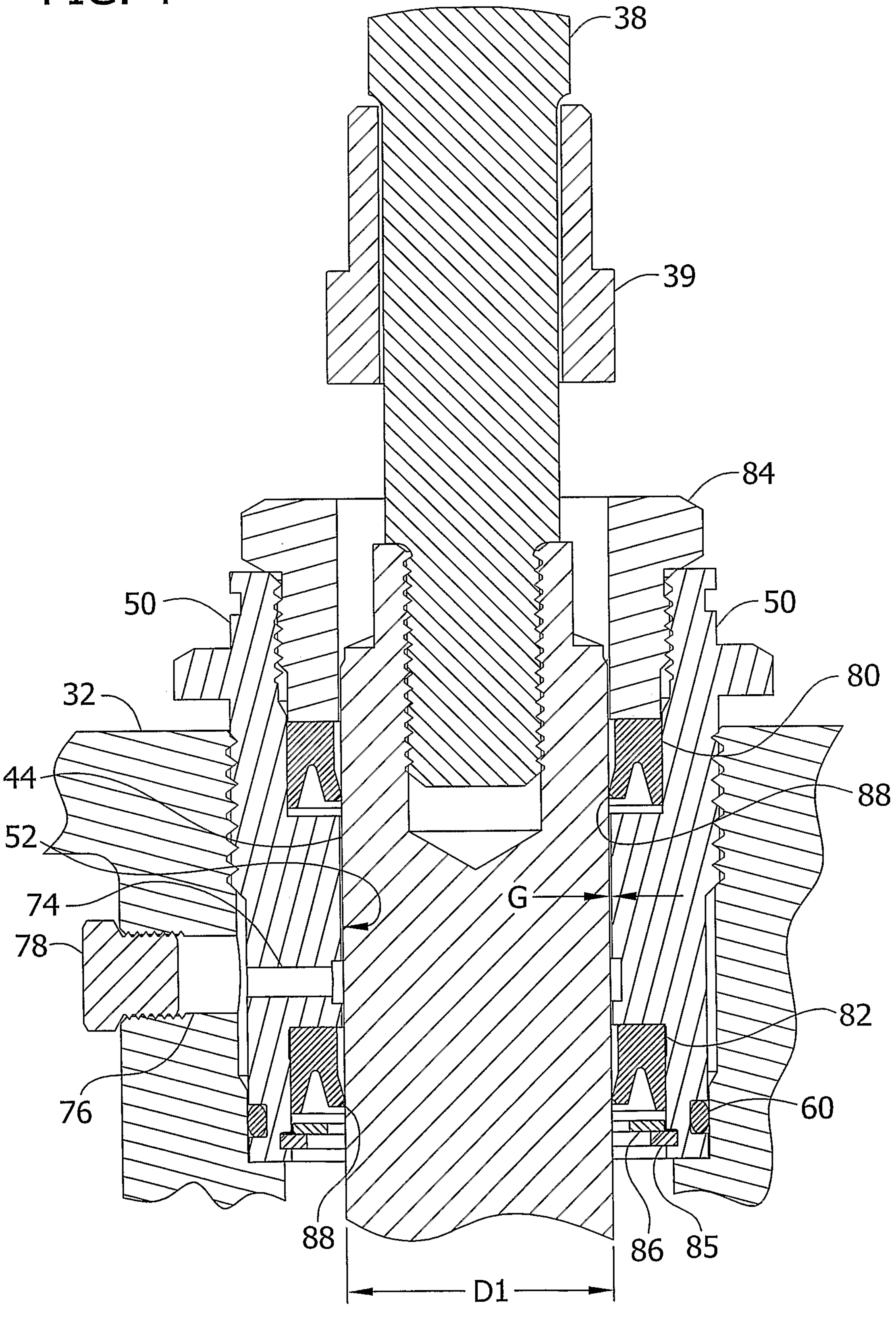

FIG. 5

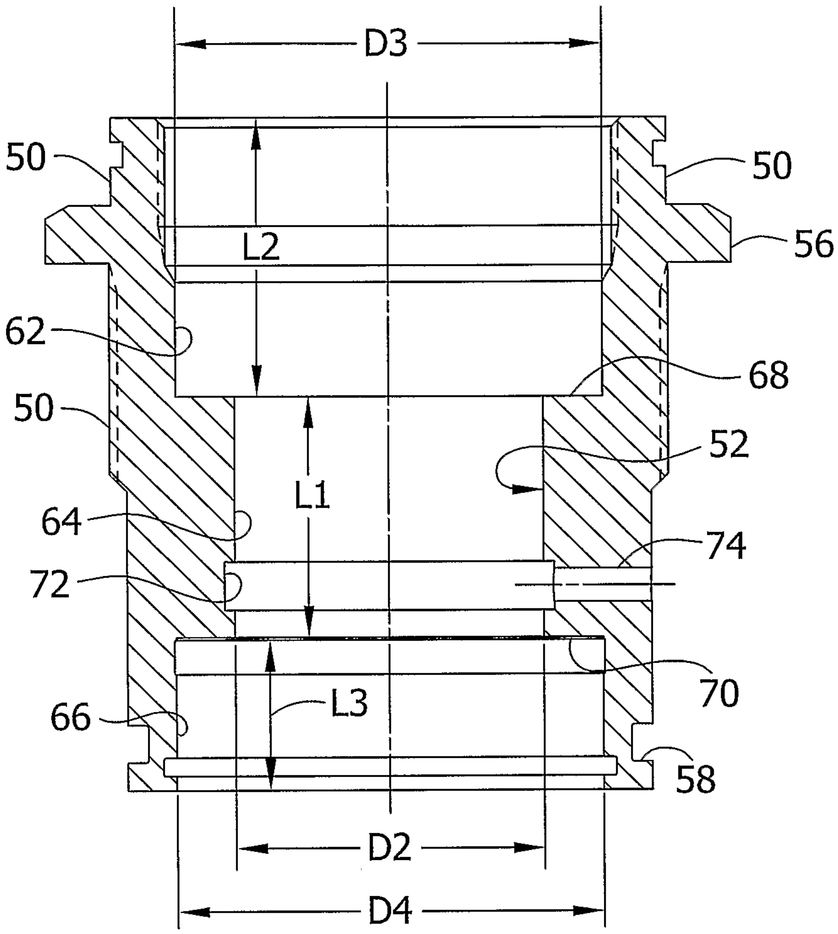

FIG. 6