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Love et al.

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[54] **FLUID END FOR A PLUNGER PUMP**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 179,705, Sept. 13, 1971, abandoned.

[52] **U.S. Cl.** **417/454,** 92/128, 137/515.5, 417/569

[51] **Int. Cl.** **F04b 39/14**

[58] **Field of Search** 417/437, 454, 568, 569, 417/570, 571, 572, 567; 92/128; 137/515, 515.3, 515.5, 454.4; 285/367

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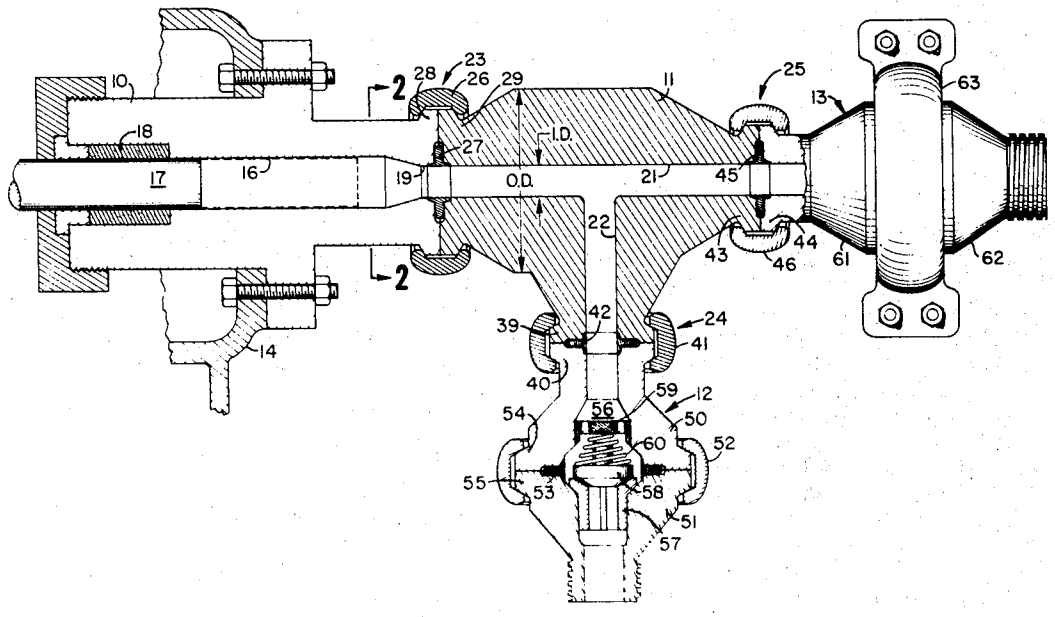
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[57] **ABSTRACT**

An improved cylindrical fluid end construction for a plunger pump includes a cylinder body, a crossbore body, and suction and discharge valve cages. The components are assembled together by quick-disconnect couplings having self-energizing seals for pressure sealing the joints. The diameters of flow passages formed in the crossbore body are less than that of the pump plunger.

6 Claims, 4 Drawing Figures



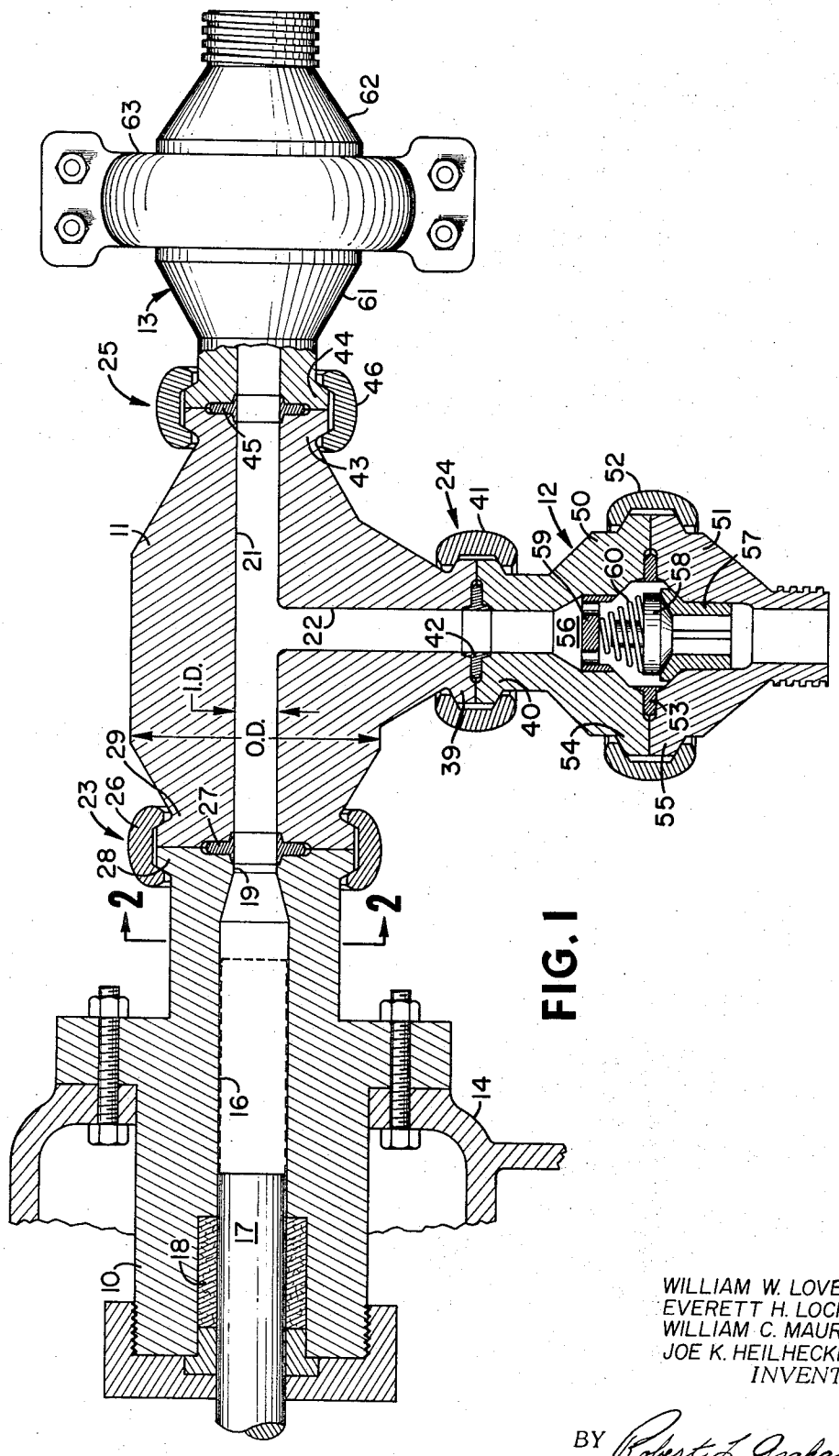


FIG. 1

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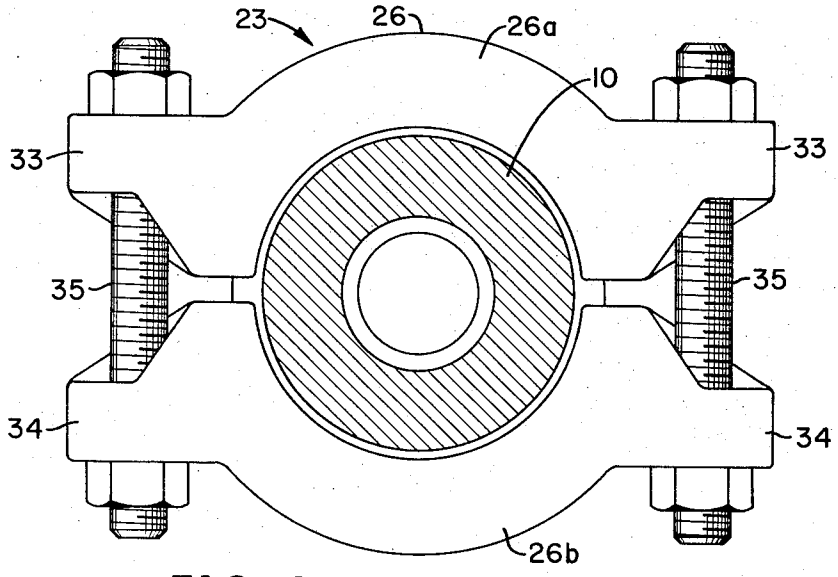


FIG. 2

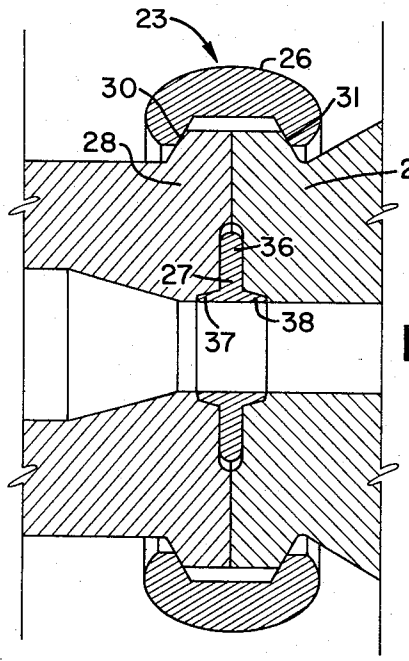


FIG. 3

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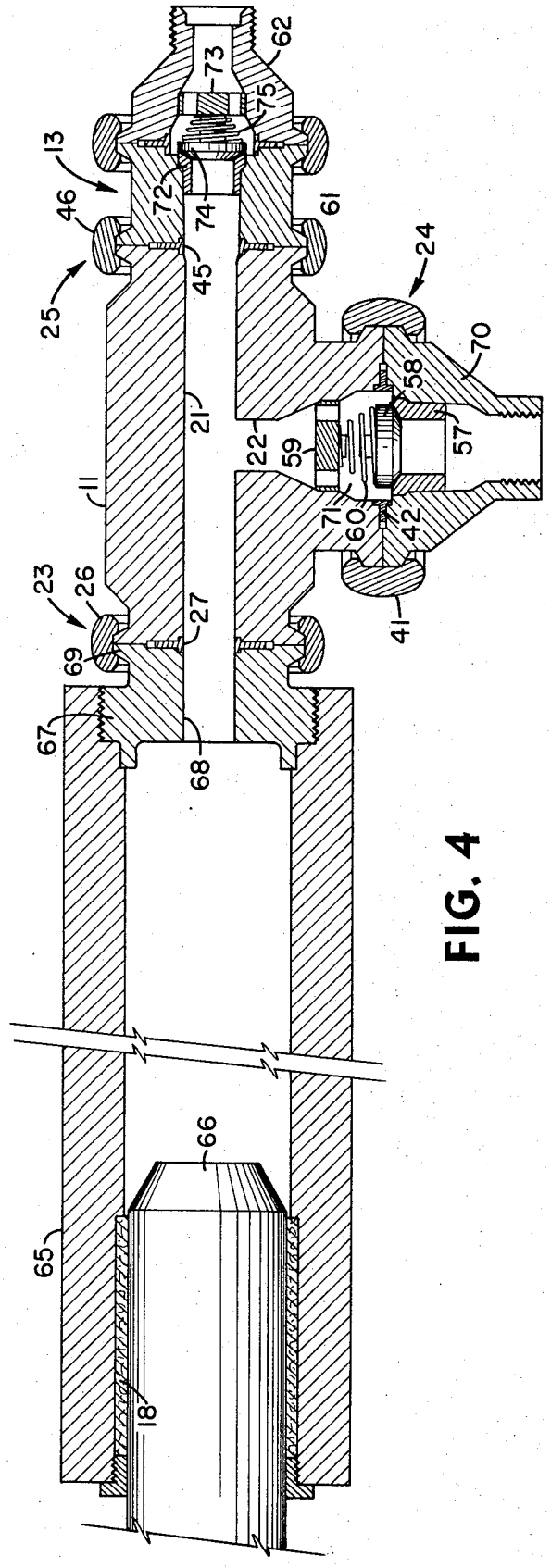

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FIG. 4

FLUID END FOR A PLUNGER PUMP

CROSS REFERENCE TO RELATED APPLICATION

This application is a Continuation-In-Part application of Ser. No. 179,705, filed in the United States Patent Office on Sept. 13, 1971, now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an improved fluid end construction for a plunger pump.

2. Description of the Prior Art

Multiplex plunger pumps are used in a variety of oil field operations which require the pumping of fluid at high volumes and at high pressures. In many of these operations, it is important that the pumps be capable of operating for relatively long periods of time and that when failure does occur the pump be capable of repair with a minimum of shutdown time. Experience with plunger pumps has shown that the failure generally occurs in the fluid end of the pump. A recent improvement in plunger pumps involves a sectionalized construction wherein the components of the fluid end are made separately and assembled together as a unit. The sectionalized construction offers several advantages over the conventional monoblock fluid end. It permits the valves to be mounted externally of the main body thus simplifying the flow passages through the body which results in fewer stress concentration points. The sectionalized construction also reduces the cost of the structure since the separate castings or forgings are much simpler. Moreover, the sectionalized construction reduces pump repair costs since only the worn component need be replaced. The main disadvantage of this type of construction is that it requires several more joints. These joints present points of weakness in the assembly because of the inability of the couplings to withstand the fluctuating loads for long periods of time. The components of the sectionalized fluid end, heretofore, have been assembled by flange connections which employ face seals to pressure seal the joints. These flange connections have not proven entirely satisfactory in plunger pumps operated at high pressures for long periods of time. The fluctuating load associated with the plunger pump tends to loosen the bolts and/or damage the seal. Moreover, the flange connections result in a heavy bulky structure since the flanges must be capable of exerting high load on the face seal to attain a pressure seal at the joint. The heavy, bulky structure not only increases the cost of the fluid end construction, but requires a considerable amount of time and effort to replace worn valves or seals.

As mentioned previously, plunger pumps are used in certain operations which cannot tolerate long shutdown periods. For example, during the drilling of wells by rotary drilling methods, it is hazardous to interrupt the circulation of drilling fluid through the drill string and up the annulus for long periods because of the risk of sticking the drill string in the well. The drilling fluid flowing up the wellbore annulus prevents the accumulation of solids in the annulus which could cause the drill string to become stuck. It will thus be appreciated that when pump failure occurs, the pump should be capable of repair with a minimum shutdown period.

Another example where long shutdown periods cannot be tolerated is found in fracturing operations. A

fracturing fluid laden with particulate propping agents must be pumped into the formation at a minimum velocity to prevent the propping agent from settling. If this minimum velocity is not maintained, the sand settles out of the carrier fluid, accumulates in the wellbore, and plugs the formation. Here again, the shutdown period for pump repair should be maintained at a minimum.

In plunger pumps, failure generally occurs in the valve assemblies because of the cyclic operation of the valve and because of the high stresses between the valve and valve seat. In the conventional monoblock fluid end construction, the valve assemblies, located internally of the cylinder block, are not readily accessible and therefore generally require several hours to replace. Even in the sectionalized fluid end construction which employ flange connections, valve replacement cannot be quickly performed.

SUMMARY OF THE INVENTION

The present invention provides an improved sectionalized fluid end for a plunger pump which because of its unique construction offers several advantages over plunger pumps of the prior art. Briefly, the fluid end comprises a cylinder body through which reciprocates a plunger, a crossbore body having flow passages formed therein, and suction and discharge valve cages secured to the crossbore body. Each of these components is constructed separately and assembled as a unit. A novel feature of the present invention involves the coupling means for assembling the various components of the fluid end structure. A self-energizing seal ring provides a fluid-tight seal at the joint, and a quick-disconnect clamping collar maintains the parts in assembled relation. As used herein, the term self-energizing seal contemplates the type of seal which is activated by internal pressure. In other words, the contact pressure between the seal and the members being joined increases with internal pressure. It should be noted that the effectiveness of such a seal is primarily due to the internal pressure and not the force exerted by the coupling. This permits the use of the clamping collar which is designed primarily to resist the pressure load. The use of clamping collars instead of the flange connections substantially reduces the weight and bulk of the structure. Moreover, the combination of the self-energizing seal and the clamping collar resists bolt loosening and seal ring damage. When it becomes necessary to replace one of the valves, the clamping collar can be quickly disassembled and a new valve cage substituted for the valve cage containing the damaged valve. Experience has shown that a valve cage can be replaced in about five minutes which is only a fraction of the time required to replace a valve cage joined by a flange connection. Because of this quick valve replacement feature, the fluid end construction of the present invention is ideally suited for drilling and fracturing operations.

Another feature of the present invention involves use of reduced diameter flow passages in the crossbore body of the sectionalized fluid end. It is known that in order to reduce the stress concentration at the intersection of the flow passages in the crossbore body, the ratio of the body diameter to the flow passage diameter should be in the order of four or more. In most plunger pumps, the flow passages through the crossbore are sized to receive the plunger reciprocating therein. By

basing the flow passage size on flow rate instead of plunger size, the inside diameter and outside diameter of the crossbore body can be substantially reduced resulting in a much smaller and lighter structure. This not only reduces the cost of the part but permits the multiplex pump to be assembled in a compact structure.

As mentioned previously, the present invention also contemplates the use of valve cages adapted to be mounted externally of the crossbore body by quick disconnect couplings which permit rapid replacement of worn valves.

In summary, the fluid end construction of the present invention involves several novel features which individually and collectively offer advantages over prior art fluid ends. The improved fluid end construction provides a compact structure; the clamping collars lend a quick-disconnect feature to the assembly; and the self-energizing seals alleviate the damaging effects of the fluctuating load conditions.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevational view shown partially in section of fluid end for a plunger pump constructed according to the present invention.

FIG. 2 is an enlarged sectional view of the coupling means used to join the crossbore body to other components of the sectionalized fluid end.

FIG. 3 is a fragmentary, longitudinal sectional view of the coupling means shown in FIG. 2.

FIG. 4 is a side elevational view of a fluid end construction similar to FIG. 1 illustrating a slightly modified form of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

As shown in FIG. 1, the fluid end for a plunger pump comprises several individual components assembled as a unit by couplings which feature quick-disconnect clamping collars and self-energizing seals. The components can be forged from steel alloys or other materials commonly used in high pressure pumps and can be machined separately to provide the proper configurations. It should be noted that the individual components are simple in structure which facilitates the forging and machining operations.

Briefly, the fluid end comprises a cylinder body 10, a crossbore body 11, a suction valve cage 12 and a discharge valve cage 13. The cylinder body 10 is secured to the pump frame 14 and has a longitudinal bore 16 formed therein. A plunger 17 is mounted in the bore 16, with a packing assembly shown generally as 18 providing a seal between the cylinder body 10 and the plunger 17. The forward end of the bore 16 tapers to a reduced diameter section 19 which, as pointed out below, registers with a flow passage formed in the crossbore body 11. The plunger 17 is connected to the power end (not shown) of the pump which reciprocates the plunger 17 within the cylinder body 10 between the solid line and broken line positions shown in FIG. 1. The power end may be a crank-type drive or a hydraulic drive.

The crossbore body 11 has a pair of crossbores or flow passages 21 and 22 formed therein. The corners of the flow passage walls in the area of intersection are rounded to reduce stress concentration points. Since the plunger 17 does not enter the crossbore body 11, the flow passages 21 and 22 can be sized on the basis of desired volumetric flow rate rather than on the basis of the plunger diameter. The flow passages 21 and 22 are thus made large enough to prevent the maximum instantaneous velocity at the desired flow rate from exceeding about 40 feet per second. Fluid velocities in excess of this limit tend to erode the walls of the flow passages. Sizing based on the flow rate parameter permits the flow passages to be made much smaller in diameter than the plunger size. For most applications the ratio of plunger diameter to the diameter of the flow passages will be 2 or more. The reduced diameter flow passages permit proportionate reduction in the outside diameter of the crossbore body 11. In order to minimize stress concentrations on the internal surfaces of the crossbore body 11, the ratio of the outside diameter (OD) to the inside diameter (ID) of the crossbore body 11 should be 4 or more. Thus by reducing the diameter of the flow passages 21 and 22, the outside diameter of the body 11 can be reduced proportionately resulting in a much smaller member. This not only reduces the cost of the member—since less material is required—but also produces a smaller, more compact structure.

As mentioned previously, the ratio of the plunger diameter to the flow passage diameter should be at least 2 to effect substantial reductions in the size of the crossbore body 11. The reduced diameter flow passages in crossbore body 11 also affect the efficiency of the plunger pump. The clearance volume of the fluid end should be as small as possible to avoid substantial reductions in volumetric efficiency. Clearance volume is the difference between the fluid volumes of the assembly with the plunger in the solid line and in the broken line position of FIG. 1. The reduced diameter passages 21 and 22 in the crossbore body 11 provide less clearance volume than the same construction having full opening flow passages.

The flow passage 21 is aligned with section 19 of bore 16 and extends horizontally through the crossbore body 11. The flow passage 22 intersects the flow passage 21 at about the mid-point of the latter. It should be noted that while the crossbore body 11 disclosed in this embodiment is in the form of a T with two intersecting flow passages, other forms can be used. For example, flow passages 21 and 22 need not intersect but instead can communicate directly with the bore 16 of the cylinder body 10.

The crossbore body 11 is joined to the other three components of the fluid end construction, e.g. cylinder body 10, suction valve cage 12, and discharge valve cage 13, by means of coupling assemblies shown generally as 23, 24 and 25, respectively.

As shown in FIG. 1, and in more detail in FIGS. 2 and 3, the coupling assembly 23 which joins the crossbore body 11 and cylinder body 10 comprises a clamping collar 26 and a self-energizing seal ring 27. Mating hubs 28 an 29 formed, respectively, in the cylinder body 10 and crossbore body 11 are provided with tapered shoulders 30 and 31 which are particularly shaped to mate with interior surfaces of collar 26. With the hubs 28 and 29 arranged in mating relationship, the clamping collar 26 which can be C-shape in cross section engages the tapered shoulders 30 and 31. As shown in FIG. 2, the collar 26 is split comprising collar segments 26a and 26b. The collar 26a and 26b are provided with mounting ears 33 and 34, respectively, through which pass tangential clamping bolts 35.

The seal ring 27 which can be made of steel or other hard alloy includes a rigid rib 36 and two laterally extending lips 37 and 38. The rib 36 fits between confronting surfaces of hubs 28 and 29 while the lips 37 and 38 sealingly engage internal surfaces formed in the hubs 28 and 29. The metal-to-metal engagement of the lips 37 and 38 on the hub surfaces extends in a transverse direction with respect to the joint so that internal fluid pressure tends to increase the contact pressure between the mating members. This type of seal is known in the art as a self-energizing seal. The function of the rib 36 is to prevent overtightening of the collar which could damage the lips 37 and 38.

The parts are assembled by placing the seal ring 27 between the hubs 28 and 29, placing the split collar around the shoulders 30 and 31, and tightening the clamping bolts 35. As the collar segments 26*a* and 26*b* are drawn together, the hubs 28 and 29 are axially thrust together until they engage opposite sides of the rib 36. The sealing lips 37 and 38 deformably engage the internal surfaces of the hubs 28 and 29, respectively, in attaining the fluid seal thereon. The clamping collar 26 thus applies in initial load on the seal ring 27 to deform the lips 37 and 38. The self-energizing characteristic of the seal, however, plays a major role in providing and maintaining the fluid-tight seal at the joint.

The coupling assemblies 24 and 25 are similar in structure to that of assembly 23. Specifically, coupling assembly 24 comprises a split collar 41 which clamps together hubs 39 and 40 formed, respectively, in crossbore body 11 and the valve cage 12. A self-energizing seal ring 42 provides a fluid-tight seal at the joint.

The coupling assembly 25 for joining the crossbore body 11 and the discharge valve cage 13 likewise comprises a split collar 46 clamping together mating hubs 43 and 44 formed, respectively, in the crossbore body 11 and the discharge valve cage 13. A self-energizing seal ring 45 positioned at the joint maintains the assembly in a fluid-tight relationship.

From the foregoing it is apparent that the coupling assemblies 23, 24 and 25 have in common the clamping collars and the self-energizing seal rings. A variety of clamping collars and self-energizing seals are commercially available. The coupling and seal arrangement described above and depicted in the drawings, is similar to that sold under the tradename Grayloc manufactured by Gray Tool Company. Another type of coupling usable in the present invention is the Vickers-Anderson coupling described in High Pressure Engineering, published by The Chemical Rubber Company, 1971. The Vickers-Anderson coupling is a split collar comprising three segments which are held together by tangentially extending bolts. This type of coupling can be used with a self-energizing seal ring for joining the parts in a fluid-tight assembly.

The sectionalized fluid end construction assembled by the clamping collars and self-energizing seal rings offers several advantages over fluid end constructions which employ flange connections. The fluctuating load characteristic of plunger pumps does not tend to loosen the mounting bolts as it does in the case of flange connections; the clamping collars can be much smaller in size than the flanges; and, finally, the quick-disconnect feature of the clamping collars permits rapid replacement of parts.

As described above, the suction and discharge valve cages 12 and 13 housing their respective valve assemblies may be preassembled as a unit and are mounted externally of the crossbore body 11 by the quick-disconnect couplings 24 and 25. The suction valve cage 12 as shown in FIG. 1 is in the form of a split housing comprising members 50 and 51. The housing members 50 and 51 are joined together by means of a clamping collar 52 with a self-energizing seal ring 53 being provided at the joint. The clamping collar 52 engaging mating shoulders 54 and 55 maintain the housing members 50 and 51 in assembled relation. The clamping collar 52 is split with the segments being connected together by tangentially extending bolts in the manner previously described. The housing members 50 and 51 in combination define an internal valve chamber 56 which contains the valve assembly. The self-energizing seal ring 53 which can be a Grayloc seal as previously described provides a fluid-tight seal at the joint. The surface engagement of the seal ring 53 on internal surfaces of members 50 and 51 extends transversely with respect to the joint so that pressure in chamber 56 tends to increase the contact pressure and thereby provides a self-tightening effect.

The valve assembly mounted in cage 12 is conventional comprising valve seat 57, a skirted valve 58, retainer 59, and spring 60. The valve seat 57 and retainer 59 can be press fit, respectively, into members 51 and 50 with the spring 60 being positioned between the retainer 59 and valve 58 to maintain the valve in a normally closed position.

The inlet end of the valve cage 12 is threaded for connection to a suction line (not shown) by means of a union or other quick-disconnect type coupling. As mentioned previously, the valve cage 12 discharges into the flow passage 22 of crossbore body 11.

The discharge valve cage 13 may be similar in structure to the suction valve cage 12 comprising housing members 61 and 62 coupled together by a clamping collar 63 with a self-energizing seal (not shown) being provided by the joint. The valve assembly contained in the discharge valve cage 13 includes a valve seat, a skirted valve, a retainer, and a spring arranged in the conventional manner. The inlet of the valve cage 13 is aligned with flow passage 21. The discharge end of the valve cage 13 is threaded for connection to a high pressure line by means of a union or other quick-disconnect type coupling (not shown).

FIG. 4 illustrates a slightly modified version of the fluid end construction which may be useful in designs that present space limitations for the externally mounted valve cages. The fluid end construction in this embodiment is illustrated in connection with a hydraulic high-pressure intensifier pump which includes a large diameter barrel or cylinder body 65 having a plunger 66 reciprocably mounted therein. Plunger 66 extends beyond the rear extremity of cylinder body 65 through a suitable packing and connects to a hydraulic power end (not shown). The hydraulic power end includes a power piston assembly driven by power fluid from conventional pumps. The piston is substantially larger in diameter than the plunger 66. The pumping pressure of an intensifier pump is approximately the power fluid pressure amplified by a factor equal to the ratio of piston area to plunger area.

The high pressure intensifier pumps normally are provided with large diameter plungers, e.g. from about

4 inches to 8 inches, and large power pistons, e.g. from 6 inches to 12 inches which operate in a long stroke, e.g. from 48 inches to 72 inches.

Because of the high pressures developed by intensifier plunger pumps, the fluid end construction of the present invention is ideally suited for service therein. The components shown in FIG. 4 which correspond to components shown in FIGS. 1–3 and represented by the same reference numerals.

Because of the large diameter of the cylinder body 65, an adapter 67 is provided between the forward end of body 65 and crossbore body 11. Adapter 67 may threadedly connect to body 65 and for purposes of this invention, is considered to be a part thereof. Adapter 67 has a central opening 68 which has about the same diameter as flow passage 21. Coupling assembly 23 including collar 26 and ring 27 joins the crossbore body 11 to hub 69 formed in adapter 67.

The suction valve cage illustrated as 70 in FIG. 4 contains part of the suction valve assembly. Part of the suction valve assembly is mounted in an enlarged section 71 of the crossbore body 11 at the entrance of suction flow passage 22. Valve seat 57 is mounted in cage 70 and valve retainer 59 is mounted in the enlarged section 71. Valve 58 is urged into seating relation on valve seat 57 by spring 60.

The suction valve cage 70 is connected to the crossbore body 11 by coupling assembly 24 which includes clamping collar 41 and seal ring 42.

The discharge valve cage 13 may be similar in construction as suction valve cage 70 but preferably includes mated housing members 61 and 62 as shown in FIG. 4. In the former design, part of the valve assembly, e.g. valve seat 72, will be mounted in an enlarged section at the discharge of passage 21, retainer 73 in the cage 13 with the skirted valve 74 being urged into seating relation on seat 72 by a spring 75. In the latter design, the complete valve is contained in the cage 13 as illustrated. The valve cage which contains the complete discharge valve, however, is the preferred design because damage by erosion in the vicinity of the discharge valve will be on an inexpensive part, e.g. valve cage member 61. The discharge valve cage 13 is connected to the crossbore body 11 by coupling assembly 25 which includes clamping collar 46 and ring 45.

The high pressure intensifier pump operates as follow: the plunger reciprocates within housing 65 at between about 5 and 20 strokes per minute; fluid is drawn into the plunger bore through the suction valve assembly and passage 22 and discharged at a high pressure through passage 21 and discharge valve assembly. Replacement of either valve requires simply disconnecting the quick-disconnect coupling, e.g. collars 41 or 46, removing the valve cage, inserting a new valve cage, and reconnecting the coupling.

The following field test demonstrates the performance of the improved fluid end construction. The power end of a Gardner-Denver PZ 9 triplex pump was provided with three fluid ends constructed according to the present invention. The dimensions of each fluid end were as follows:

Plunger (17) — 3.5 inches	
Flow passages (21 and 22) — 1.6 inches	
OD of crossbore body — 7 inches	
Coupling assembly (23)	
hubs (28 and 29)	7½ inch Grayloc
collar (26)	7¼ inch Grayloc
seal ring (27), ID	1.609 inch Grayloc
Coupling assemblies (24 and 25)	
hubs (39, 40, 43, 44)	5½ inch Grayloc
collars (41 and 46)	5¼ inch Grayloc
seal rings (41 and 45), ID	1.609 inch Grayloc
Valve cage couplings	
hubs (54 and 55)	9¼ inch Grayloc
collars (52 and 63)	9¼ inch Grayloc
seal rings (53), ID	4.063 inch Grayloc

The pumping conditions were as follows:
Strokes per minute — 140
Average pump pressure — 8,000 psi
Fluid pumped — Bentonite drilling mud — 9.2 lb/gal.

The pump was operated for approximately 2 million cycles without leakage occurring across any of the joints. A valve failure occurring after 20 hours of operation required the replacement of valve cage 13. The total time for replacing the valve was about 5 minutes.

The field test demonstrated that the sectionalized fluid end construction of the present invention is capable of handling high pressure fluid for long periods of time. The test also illustrates that when valve failure occurs, the valve cage containing the faulty valve can be replaced in a very short period of time — usually about 5 minutes. This quick replacement feature is particularly important for pumps used in drilling and hydraulic fracturing operations.

We claim:

1. In a plunger pump, an improved fluid end construction comprising: a cylinder body having a plunger bore formed therein; a plunger mounted in said bore and adapted to reciprocably move therein; a crossbore body having suction and discharge flow passages formed therein, the diameter of each of said flow passages being substantially smaller than the diameter of said plunger; first coupling means for joining said cylinder body and said crossbore body wherein said flow passages are in fluid communication with said plunger bore; a suction valve cage containing a part at least of a suction valve; second coupling means for joining said crossbore body and said suction valve cage wherein said suction flow passage is in fluid communication with said suction valve; a discharge valve cage containing a part at least of a discharge valve; and third coupling means for joining said crossbore body and said discharge valve cage wherein said discharge flow passage is in fluid communication with said discharge valve, each of said coupling means including a segmented collar adapted to clamp together the members being joined, and a self-energizing seal ring engaging internal surfaces of each member being joined, the engagement of said seal ring on said surfaces being such that the fluid pressure internally of said seal ring tends to increase the engagement pressure.

2. The invention as recited in claim 1 wherein the ratio of the plunger diameter to the diameter of each flow passage being at least 2.

3. The invention as recited in claim 2 wherein said flow passages intersect within said crossbore body.

4. The invention as recited in claim 1 wherein each of said valve cages comprise separable housing members and coupling means for joining the housing members together, said coupling means including a segmented collar adapted to clamp said housing members together and a self-energizing seal ring engaging an internal surface of each housing member.

5. The invention as recited in claim 1 wherein said discharge valve cage contains the complete discharge valve.

6. The invention as recited in claim 1 wherein said suction valve cage contains the complete suction valve.

* * * * *