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RECIPROCATING PUMPS

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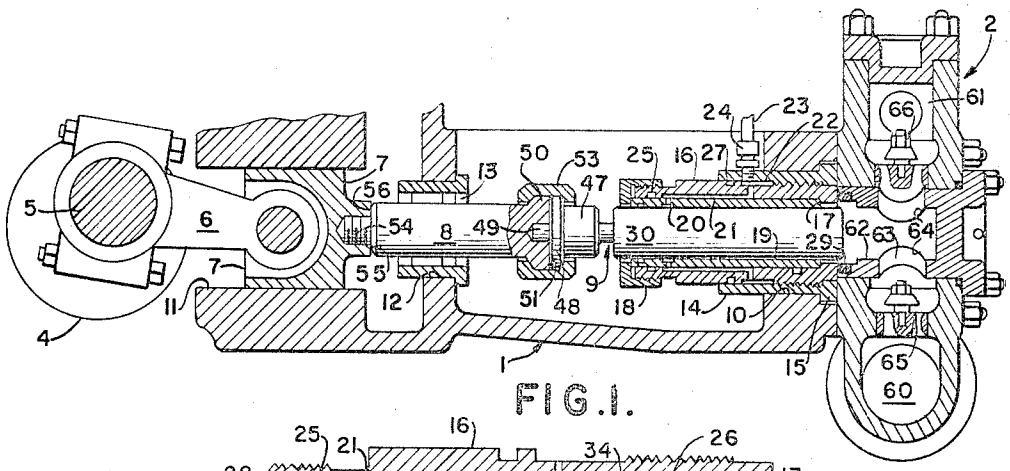


FIG. 1.

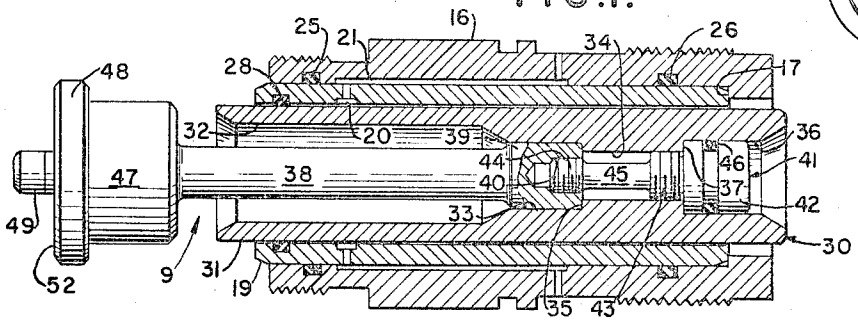


FIG. 2.

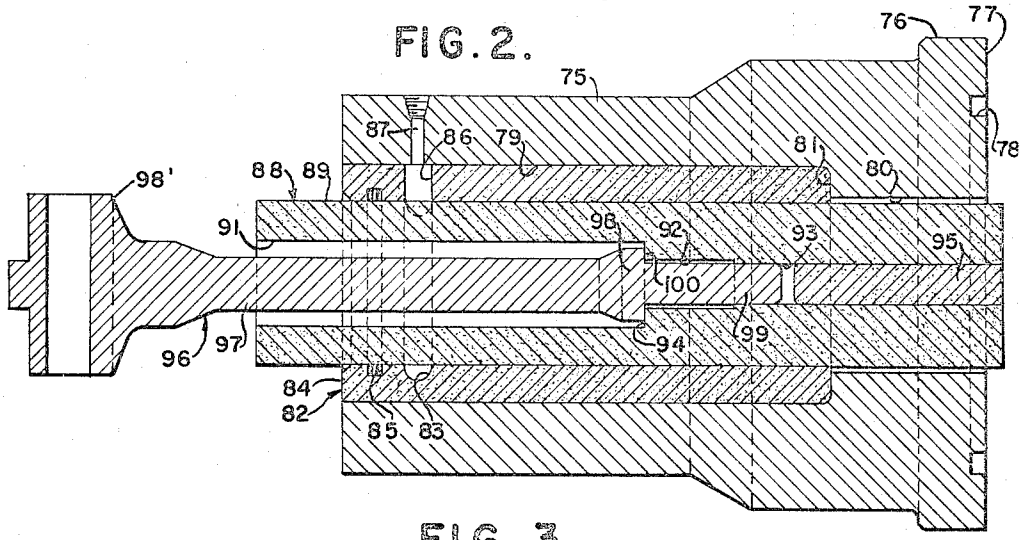


FIG. 3.

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RECIPROCATING PUMPS

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This invention relates to reciprocating pumps and more particularly to heavy duty pumps such, for example, as those employed in the oil fields for water flooding and like purposes where high fluid pressures must be maintained for prolonged periods.

For such heavy duty applications, it is common practice to employ reciprocating plunger pumps having a plurality of plungers arranged side-by-side and all driven from a single crankshaft. In such pumps, each plunger is connected to a cross-head by an intermediate rod, and the plunger, intermediate rod and crosshead all work within cylindrical surfaces which are arranged in axial alignment with each other. Ordinarily, such cylindrical surfaces are formed in an integral frame member and therefore can be bored on one machine with a single setting, so that substantially perfect coaxial alignment is attainable. Maintenance of such perfect alignment is not possible, however, in the completed assembly, since the plunger is associated with a surrounding liner and liner housing, and the intermediate rod is associated with a rod seal. Though the two cylindrical bores which house the liner housing and rod seal, respectively, may be in perfect coaxial alignment, it is impractical to assume that perfect alignment can also be achieved, in the final assembly, between the inner surface of the liner and the inner diameter of the rod seal.

Despite the difficulties involved in attempting to achieve coaxial alignment of such elements as the liner and plunger relative to the bores in the frame, such alignment is demanded if the plunger, intermediate rod and crosshead are to be rigidly interconnected, a feature which is highly desirable if the effects of impact are to be minimized during operation of the pump. Heretofore, no truly satisfactory solution to these problems has been achieved, and it has been the practice to adopt such compromises as the provision of a loose joint, between the plunger and the intermediate rod, to compensate for axial misalignments in the overall plunger assembly.

It is a general object of this invention to devise a structure, particularly applicable to heavy duty reciprocating plunger pumps, wherein the plunger, intermediate rod and crosshead are all rigidly interconnected, yet inherent small axial misalignments are tolerated.

Another object is to provide, for such pumps, a plunger assembly in which the crosshead, intermediate rod and plunger are all rigidly interconnected axially of the assembly, but provision is made for lateral flexing adequate to compenaste for axial misalignments in the assembly.

A further object is to provide an improved plunger assembly for heavy duty reciprocating pumps.

Yet another object is to provide, in a plunger pump of the type described, means for assuring that, in the event of breakage in the plunger drive, the corresponding pump chamber will remain sealed, and the other plunger units can continue normal operation without further significant damage.

Stated generally, the invention employs a plunger in the form of a rigid sleeve, and a mandrel extending within the sleeve and secured thereto, the mandrel being rigidly joined to the intermediate rod which is in turn fixed to the crosshead, provision being made for flexing of the mandrel in response to the side or lateral loads which occur, during operation of the pump, as a result of unavoidable minor axial misalignments. In certain embodiments, the mandrel is made in two parts, including a main mandrel body and an attaching bolt which forms an extension thereof within the plunger sleeve, and the attaching bolt is provided with a portion of reduced diameter capable of fracturing in the event that excessive friction is encountered during the suction stroke of the plunger. In other embodiments, the mandrel is made as an integral unit capable of flexing under acceptable lateral loads and also including a special portion of reduced diameter to assure breakage at that point in event of an excessive frictional load during the suction stroke. In all cases, provision is made for free stroking of the broken mandrel during continued operation of the pump, and for maintaining the interior of the plunger sealed so as to prevent loss of fluid from the pump chamber as a result of breakage of the mandrel.

In order that the manner in which the foregoing and other objects are attained in accordance with the invention can be understood in detail, particularly advantageous embodiments thereof will be described with reference to the accompanying drawings, which form a part of this specification, and wherein:

FIG. 1 is a fragmentary longitudinal sectional view, with some parts shown in side elevation, taken on the axis of one plunger assembly of a heavy duty multiple plunger pump constructed in accordance with one embodiment of the invention;

FIG. 2 is a longitudinal sectional view, enlarged as compared to FIG. 1, of the plunger and cylinder arrangement of the pump shown in FIG. 1; and

FIG. 3 is a view, similar to FIG. 2, illustrating a plunger and cylinder arrangement, useful in the pump of FIG. 1, constructed in accordance with another embodiment of the invention.

Turning now to the drawings in detail, and first to FIGS. 1 and 2, the invention is illustrated as applied to a heavy duty reciprocating pump comprising an integral, rigid frame member **1** and a fluid end assembly **2**, the latter defining three pump chambers. A plunger assembly **3** is provided for each pump chamber, each plunger assembly being driven by a crankshaft **4** through the combination of a crankpin **5**, connecting rod **6**, crosshead **7**, intermediate rod **8** and plunger mandrel **9**.

Frame member **1** is provided with a cylindrical bore **10**, within which the plunger assembly and associated elements are disposed, a cylindrical bore **11** within which the crosshead **7** reciprocates, and a cylindrical bore **12** in which is mounted a rod seal **13**. Since member **1** is rigid and integral, bores **10–12** can be made with a single machine setting and, therefore, can be in virtually perfect axial alignment.

A bushing **14** is mounted in bore **10** and has an outwardly extending annular end flange **15** engaged between a shoulder on the frame member and the adjacent face of the fluid end assembly. The bushing has interior threads which engage exterior threads on the liner housing member **16**. The liner housing member is disposed with one end directly abutting the adjacent face of the fluid end assembly and has an interior transverse annular shoulder **17** which faces toward the opposite end of the housing member, the latter end being threaded exteriorly to accept the linear clamp or gland nut **18**. Liner **19** is a cylindrical sleeve having one end held in engagement with shoulder **17** by the action of nut **18**. The liner sleeve has an internal transverse annular groove **20** connected by radial ports to an annular space **21** between the sleeve and housing member **16**, the annular space **21** in turn being connected by radial ports to annular space **22** between the housing member and bushing **44**. A suitable tube **23** is connected to space **22** by fitting **24**, the

tube leading back to the suction side of the pump so that fluid leakage is returned to the fluid end assembly.

Annular seals are provided between the liner sleeve and the housing member at 25 and 26, and between the housing member and bushing at 27. The liner sleeve has an internal seal at 28, between groove 20 and the end of the sleeve opposite the fluid end assembly. A seal 29 is provided between housing member 16 and the adjacent surface presented by the fluid end assembly.

The plunger 30 is generally in the form of a sleeve having a plain cylindrical outer surface 31. Commencing at the end of the plunger nearer the crosshead, the plunger has portions 32, 33 and 34 of progressively smaller internal diameter, there being a transverse annular shoulder 35 between portions 33 and 34. At its other end, the plunger has a portion 36 of larger diameter than portion 34, there being a transverse annular shoulder 37 between portions 34 and 36. With the plunger in assembled position in the pump, shoulder 35 faces toward the crosshead while shoulder 37 faces toward the fluid end assembly.

In usual cases, the clearance between the plunger 30 and the liner sleeve 19 is less than $\frac{1}{1000}$ inch, so that the plunger is firmly constrained to a position which may or may not be coaxial with respect to bores 10–12.

Mandrel 9 comprises an elongated shank 38 and an enlarged cylindrical head 39, the latter having an outer diameter such as to be snugly embraced by plunger portion 33 and a transverse end face capable of flush engagement with shoulder 35. Head 39 has an axially extending threaded bore 40, the length of the bore being shorter than that of head 39.

The mandrel 9 is secured to the plunger 30 by a bolt 41 having a cylindrical head 42 and a shank comprising two threaded portions 43 and 44 separated by a portion 45 of reduced diameter. Of a diameter to fit snugly within portion 36 of the plunger, head 42 has a transverse annular outwardly opening groove which retains an O-ring or like sealing element 46. Adjacent threaded portion 43, the bolt head presents a transverse annular shoulder capable of flush engagement with shoulder 37 of the plunger. Threaded portion 43 of the bolt is engaged with interior threads on portion 34 of the plunger adjacent shoulder 37, while the threaded tip portion 44 of the bolt is engaged with the interior threads of bore 40 in the mandrel head. Accordingly, when the mandrel and plunger are assembled as seen in FIG. 2, the plunger portion 34 is securely clamped between the bolt head 42 and the mandrel head 39, so that the plunger and mandrel are connected together with complete rigidity insofar as axial loads in either direction are concerned.

Shank portion 45 of the bolt is of significantly smaller diameter than any other portion of the mandrel assembly constituted by the mandrel and bolt. Further, the internal diameter of plunger portion 34 is larger than the diameter of shank portion 45, so that there is an annular space surrounding shank portion 45 throughout the total length thereof.

The shank 38 of mandrel 9 has a diameter which is small as compared to the diameter of the intermediate rod 8. Also, the length of mandrel shank 38 is great as compared to the mandrel shank diameter, the ratio of length-to-diameter of the mandrel shank approaching 7:1 in the particular embodiment illustrated. Accordingly, the shank of the mandrel provides a degree of "limberness" or flexing ability in the plunger-mandrel-intermediate rod assembly which is adequate to compensate for axial misalignments between plunger 30 and bores 10–12, for example. In this regard, it is to be noted that the internal diameter of plunger portion 32, within which most of the length of the mandrel shank is accommodated, is considerably larger than the diameter of the mandrel shank, so that complete freedom for flexing of the mandrel shank is allowed.

At its end opposite head 39, mandrel 9 has an enlarged cylindrical portion 47, an outwardly projecting transverse annular flange 48 and an axially projecting extension 49. The cooperating end of intermediate rod 8 has an outwardly projecting transverse annular flange 50 of the same diameter as flange 48, and is provided with an axial bore dimensioned to snugly accommodate extension 49. At flanges 50 and 48, the intermediate rod and the mandrel have flat end faces 51 and 52, respectively, capable of flush engagement. The intermediate rod and the mandrel are held rigidly together by a split clamp 53.

At its end opposite flange 50, the intermediate rod 8 is rigidly connected to crosshead 7 by an exteriorly threaded axial extension 54 engaged in a threaded axial bore in the crosshead, the crosshead and the intermediate rod having abutting end faces 55 and 56, respectively.

From the foregoing, and with reference to FIG. 1, it will be understood that the combination of crosshead 7, intermediate rod 8, plunger mandrel 9, and plunger 30 is essentially rigid with respect to axial loads in both directions, but that the shank 38 of the plunger mandrel provides a capacity to flex or yield under such lateral stresses as may occur during operation of the pump because of failure to achieve perfect coaxial alignment of the moving and stationary parts with respect to bores 10–12.

In conventional fashion, the fluid end assembly 2 defines a suction manifold 60 and a discharge manifold 61 both common to all three pump chambers. Each pump chamber is defined by a sleeve 62 which is open at its end adjacent the corresponding plunger 30 and closed at its other end, sleeve 62 and plunger 30 being coaxial and so dimensioned that, as the crankshaft 4 is driven, the plunger can reciprocate into and out of the pump chamber sleeve. Sleeve 62 has an inlet opening 63 and a discharge opening 64, and the usual inlet valve 65 and outlet valve 66 are provided. The flat annular face at the open end of sleeve 62 is in flush engagement with the corresponding flat end face of liner housing member 16, and the seal 29 is accordingly best accommodated by a groove defined jointly by members 62 and 16.

During normal operation, the plunger 30 reciprocates freely in liner 19 as the crankshaft is driven, and operation of the pump proceeds in usual fashion, except that the plunger mandrel 9 flexes to compensate for minor axial misalignments so that frictional wear is reduced, and the axial rigidity of the plunger-mandrel-intermediate rod-crosshead assembly eliminates impacting on stroke reversals. In the event of excessive frictional loads, such as would indicate impending seizure of the sliding surfaces, breakage will occur in portion 45 of bolt 41, during the suction stroke, since portion 45 is the weakest part of the combination of reciprocating elements. Upon occurrence of such breakage, the bolt head 42, with its seal 46, remains in place within plunger portion 36, being retained by threaded portion 43. Accordingly, the pump chamber is completely sealed and operation of the pump can continue, the other plungers remaining effective. The broken plunger mandrel assembly will, of course, continue stroking, but any further damage occurring because of such action will be limited to parts which are relatively inexpensive and easily replaceable.

For ease of assembly, the head portion 42 of bolt 41 can be provided with a polygonal socket for cooperation with a conventional tool.

In the embodiment of the invention shown in FIGS. 1 and 2, the liner sleeve, the plunger, and the plunger mandrel are all of metal. FIG. 3 illustrates a modified embodiment of the invention which has the same advantages as that of FIGS. 1 and 2 but wherein the liner sleeve and plunger are of a nonmetallic material such as a suitable ceramic. In this embodiment, an integral metal housing member 75 is employed in place of elements 14 and 16 of FIGS. 1 and 2. At one end, member 75 has an an-

nular outer flange **76** and a flat end face **77** to allow clamping of the member to the fluid end assembly by an integral frame member, such as member **1**, FIG. 1, a circular axially opening groove **78** being provided to accommodate a suitable seal. Member **75** has a cylindrical bore including a portion **79** of larger diameter and a portion **80** of smaller diameter, an internal transverse annular shoulder **81** being provided between the two bore portions and facing away from end face **77**.

The non-metallic liner sleeve **82** is cylindrical, its outer surface being embraced by bore portion **79** of the housing member and one end of the liner sleeve being in engagement with shoulder **81**. The liner is secured rigidly to the housing member in any suitable conventional fashion, the precise nature of which depends upon the particular non-metallic material from which the liner sleeve is fabricated. The liner is provided with an internal transverse annular groove **83** near end face **84**, and a second groove **85** between end face **84** and groove **83**. Groove **83** is of semicircular transverse cross section. A radial port **86** is provided through the wall of the liner sleeve for communication with a port **87** in the housing member, so that the groove **83** can be placed in communication with the suction side of the pump, as by fitting **24** and tube **23**, FIG. 1, and will serve to provide a fluid seal between the plunger and liner. Groove **85** retains a mechanical sealing element, such as an O-ring.

The plunger **88** can be fabricated from a different material or from the same non-metallic material as is liner **82**. Plunger **88** has a plain cylindrical outer surface **89** and a cylindrical central bore having a portion **91** of larger diameter, an intermediate portion **92** of distinctly smaller diameter than portion **91**, and a portion **93** of a diameter slightly smaller than that of portion **92**. A transverse annular shoulder **94** is provided between bore portions **91** and **92** and faces the outer end of bore portion **91**. The outer end of bore portion **93** is closed, and sealed against entry of fluid, by a plug **95** which can be of the same material as is the plunger.

Fabricated of a suitable metal, the plunger mandrel **96** includes a shank **97** extending between an intermediate enlarged portion **98** and one portion **98'** of a pin connection by which the mandrel is joined to the intermediate rod (not shown). Beyond enlarged portion **98**, the mandrel includes a cylindrical tip portion **99** of a diameter equal to that of plunger bore portion **93**, that diameter being significantly smaller than the diameter of shank **97**. Enlarged portion **98** presents a transverse annular face **100** directed toward the free end of tip portion **99**. Tip portion **99** is substantially longer than is the intermediate bore portion **92** of the plunger.

Mandrel **96** is disposed coaxially with respect to plunger **88**, the tip portion **99** extending through bore portion **92** and into bore portion **93**. The wall of bore portion **93** embraces tip portion **99** and the two parts are rigidly joined together at this point in any suitable conventional fashion. Shoulder **94** and face **100** are in direct, flush engagement. The greater portion of shank **97** is disposed within bore portion **91**, there being a substantial annular space between the shank and the mandrel. A substantial portion of the tip portion **99** of the mandrel is within bore portion **92** and there is a significant annular space between tip portion **99** and the wall of bore portion **92**.

Recognizing that the mandrel is to be connected to an intermediate driving rod which is rigid and of relatively large diameter, as in the case of rod **8**, FIG. 1, it will be understood that shank **97** is of comparatively small diameter and affords a capability for flexing under tolerable lateral loads in the same manner as does shank **38**, FIGS. 1 and 2. Similarly, the part of tip portion **99** disposed within bore portion **92**, being of still smaller diameter, provides a predetermined point for breakage in the event that excessive frictional forces are encountered during a suction stroke of the plunger **88**. In event of breakage at this point, the plunger remains within liner **82** and material loss of fluid from the pump chamber is prevented by plug **95** and the seals between the plunger and the liner. Operation of the pump, with continued stroking of the broken mandrel, can thus continue.

Through particularly advantageous embodiments of the invention have been illustrated and described, it will be understood that various changes and modifications can be made therein without departing from the scope of the invention as defined in the appended claims.

What is claimed is:

1. In a heavy duty reciprocating pump of the type comprising a rigid frame, a fluid end assembly defining a plurality of pump chambers, a plurality of devices rigidly supported by the frame and each defining a cylindrical passage communicating with a different one of the pump chambers, and drive means including a plurality of reciprocatory members each constrained to move along the axis of a different one of the cylindrical passages, the combination of

a plurality of plunger assemblies each operatively arranged in a different one of the cylindrical passages and each comprising

a tubular plunger,

a mandrel having a shank portion extending coaxially with said plunger,

means securing said mandrel rigidly to said plunger at the end of said shank portion disposed within said plunger, and

means connecting the other end of said mandrel to one of the reciprocatory members of the drive means;

said shank portion having a transverse cross-section which is small as compared to the cross-sectional size of the one of the reciprocatory members to which said mandrel is connected, whereby said shank portion affords a limited flexing ability under misaligments affecting the reciprocatory movement of said plunger,

said means securing said mandrel to said plunger including an element which is interposed between said shank portion and said plunger and which is substantially weaker than said shank portion,

said plunger defining a free annular space about said shank portion to allow flexing of said shank portion.

2. A pump according to claim **1**, wherein

said means securing said mandrel to said plunger comprises a threaded fastener member having an enlarged head portion, a shank portion, and a threaded tip,

said plunger having an internal shoulder spaced axially from the end of said mandrel which is disposed within said plunger,

said mandrel having a threaded bore within which said threaded tip of said fastener member is engaged,

said head portion of said fastener member being in engagement with said shoulder,

said shank portion of said fastener member constituting element which is interposed between said shank portion of said mandrel and said plunger.

3. A pump according to claim **2** and further comprising annular seal means between said head portion of said fastener member and said plunger to establish a fluid-tight seal effective to prevent loss of fluid from the pump chamber via the interior of said plunger in event of breakage of said shank portion of said fastener member.

4. A pump according to claim **2**, wherein

said fastener member is threaded adjacent said head portion for screw-thread engagement with internal threads on said plunger, such screw-thread engagement retaining said head portion of said fastener member in place in said plunger after breakage of said shank portion of said fastener member.

5. A pump according to claim 1, wherein
said plunger has two internal transverse annular shoulders each facing toward a different end of said plunger,
said mandrel has a transverse face engaged with one of said shoulders, and
said means securing said mandrel rigidly to said plunger comprises a fastener member having a head portion engaged with the other of said shoulders.

6. A pump according to claim 5, wherein
said fastener member has
a threaded tip engaged in screw-thread relation with a threaded portion of said mandrel,
a plain shank portion extending from said mandrel toward said head portion, and
a threaded portion disposed between said plain shank portion and said head portion and engaged in screw-thread relation with internal threads on said plunger to retain said head portion in place in event of breakage of said plain shank portion.

7. A pump according to claim 1, wherein
said plunger has an end portion of larger internal diameter, an intermediate portion of smaller internal diameter, and a third portion of still smaller internal diameter, there being a transverse annular shoulder between said end portion and said intermediate portion,
said shank portion of said mandrel terminating at one end in a portion presenting a shoulder engaged with said transverse annular shoulder,
said mandrel including a tip portion projecting from said one end of said shank portion through said intermediate portion of said plunger into said third portion of said plunger,
said tip portion being rigidly affixed to said third portion of said plunger,
the transverse cross-section of said tip portion within said intermediate portion of said plunger being significantly smaller than the cross-section of said shank portion.

8. A plunger assembly for heavy duty reciprocating pumps comprising, in combination,

a tubular plunger having
an elongated end portion of larger internal diameter,
an intermediate portion of an internal diameter smaller than said elongated end portion, and
a second end portion having an internal diameter larger than said intermediate portion,
said intermediate portion presenting a first transverse annular internal shoulder facing toward the open end of said elongated end portion and a second transverse annular internal shoulder facing toward the open end of said second end portion,
a mandrel having a shank portion projecting axially through said elongated end portion and terminating in means presenting a transverse annular shoulder engaged with said first shoulder; and
a fastener member having a head portion, a shank, and a threaded tip,
said head portion being disposed in said second end portion and engaging said second shoulder,
said threaded tip being engaged in a threaded bore in said mandrel, and
said shank of said fastener member being disposed within said intermediate portion of said plunger and having a transverse cross-section substantially smaller than the transverse cross-section of said shank of said mandrel.

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