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Jefferies

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(54) **PLUNGER LIFT SYSTEM**

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(52) **U.S. Cl.**
CPC ***E21B 43/121*** (2013.01); ***E21B 43/123*** (2013.01)

(58) **Field of Classification Search**
CPC E21B 43/121; E21B 34/14; E21B 34/142
See application file for complete search history.

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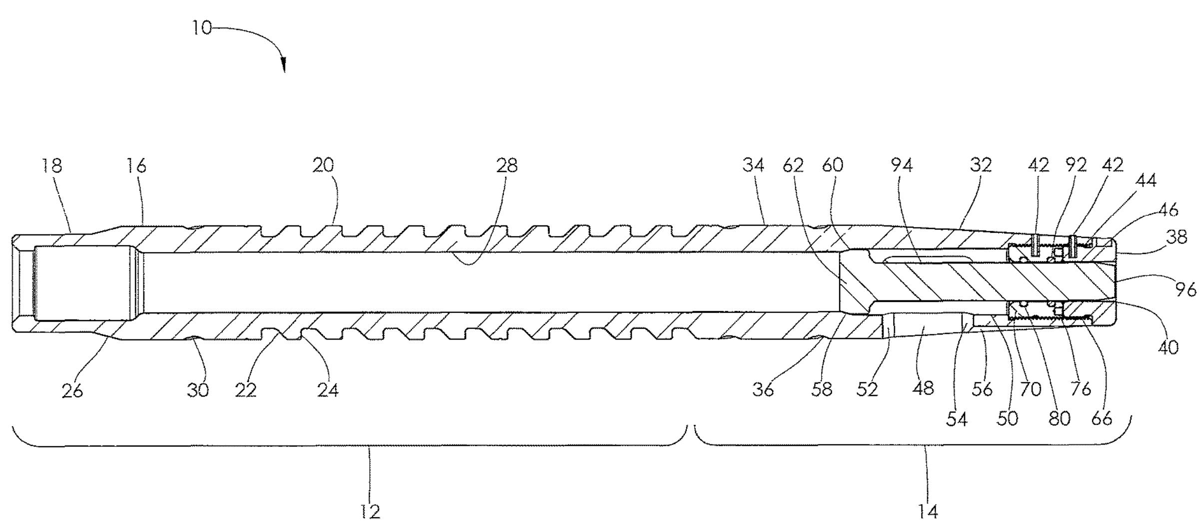
(57) **ABSTRACT**

A plunger lift system for lifting fluids in a well bore includes a plunger body having a central bore, and a bypass valve assembly disposed at a lower end of the plunger body. The bypass valve assembly includes a valve cage, a valve stem disposed at least partially within the valve cage, a clutch bobbin carried by the valve cage and being operable associated with the valve stem, and at least one canted coil spring carried by the clutch bobbin for controlling movement of the valve stem.

13 Claims, 9 Drawing Sheets



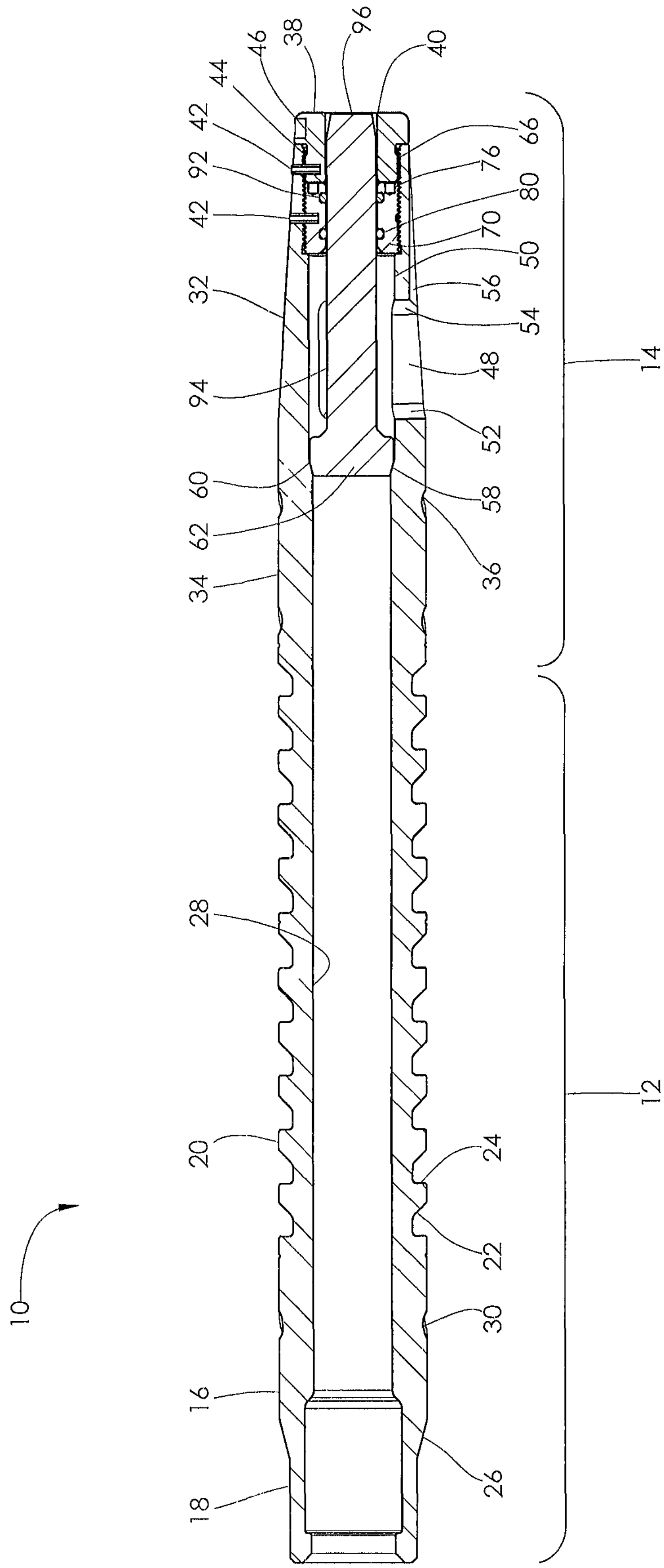

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Figure 1

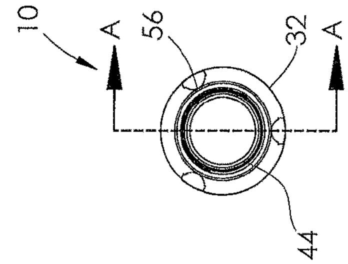

Figure 2B

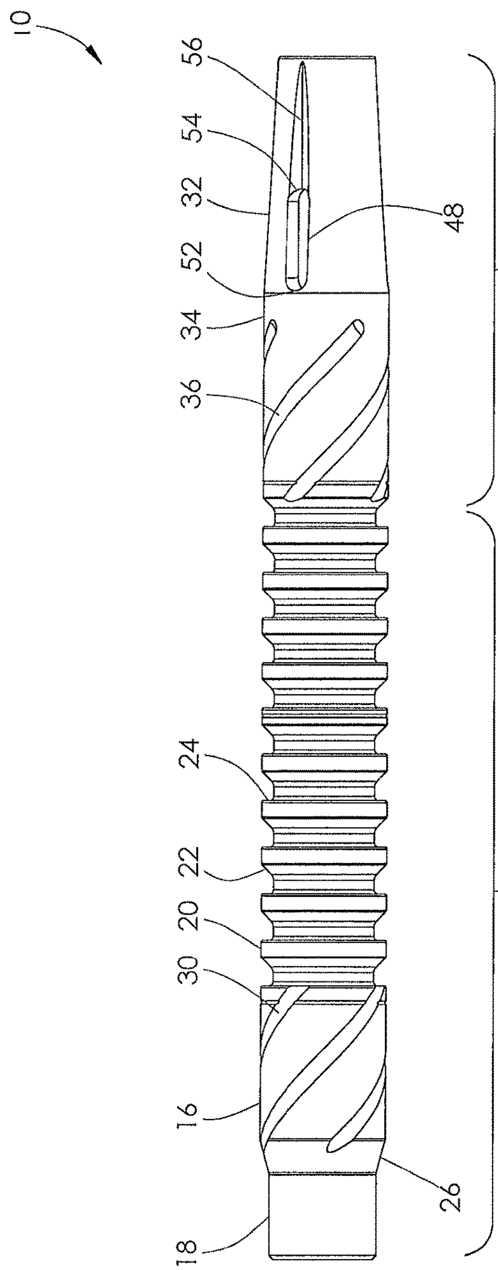

Figure 2A

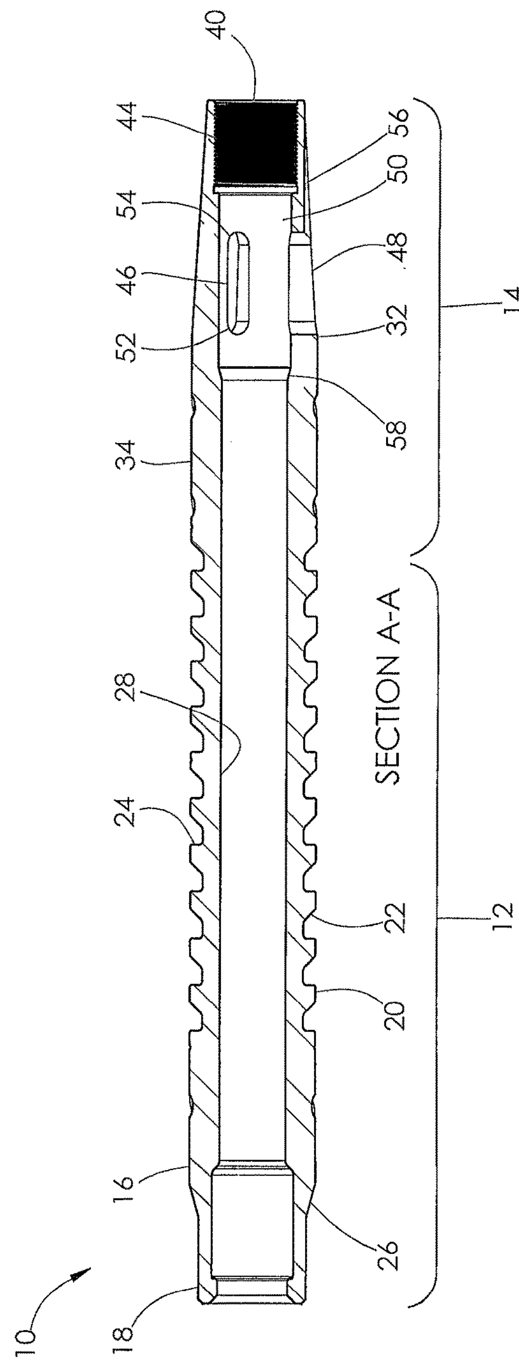

Figure 2C

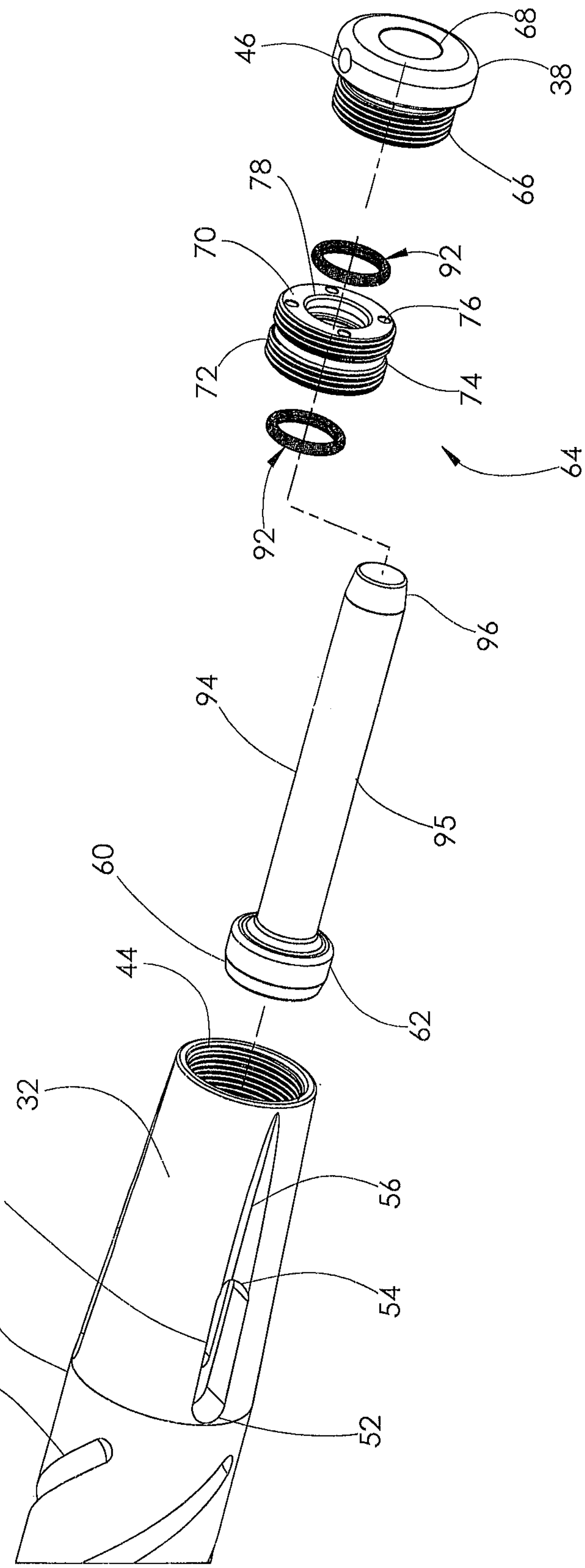
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Figure 3

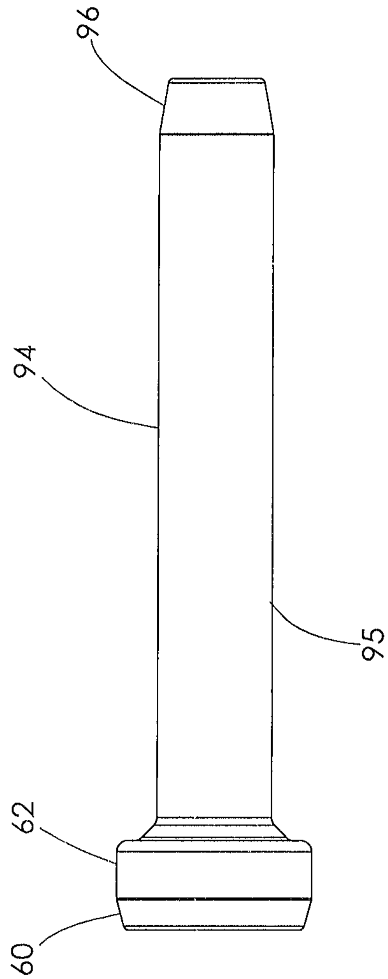


Figure 4B

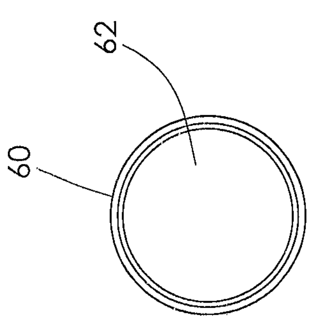


Figure 4A

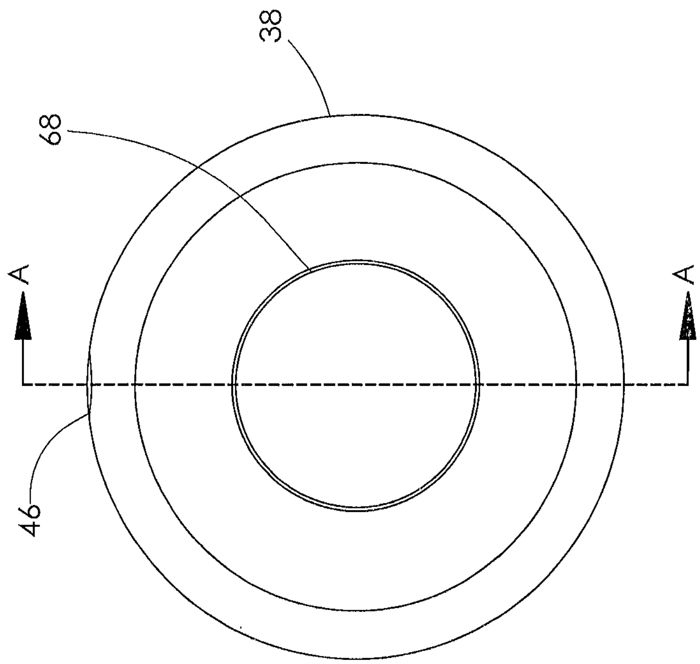
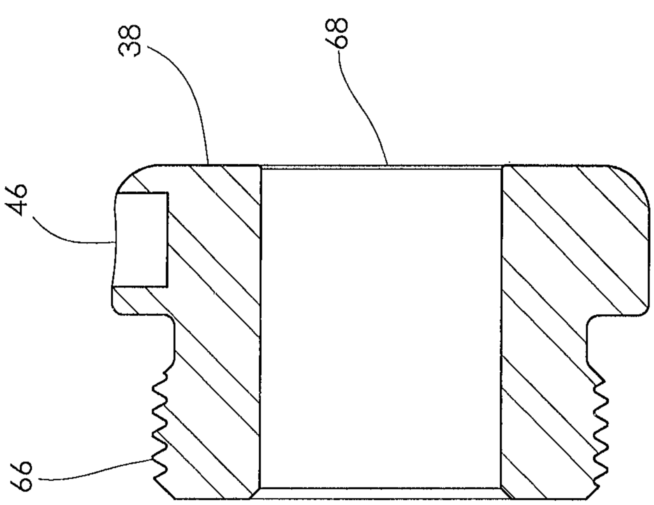


Figure 5A



SECTION A-A

Figure 5B

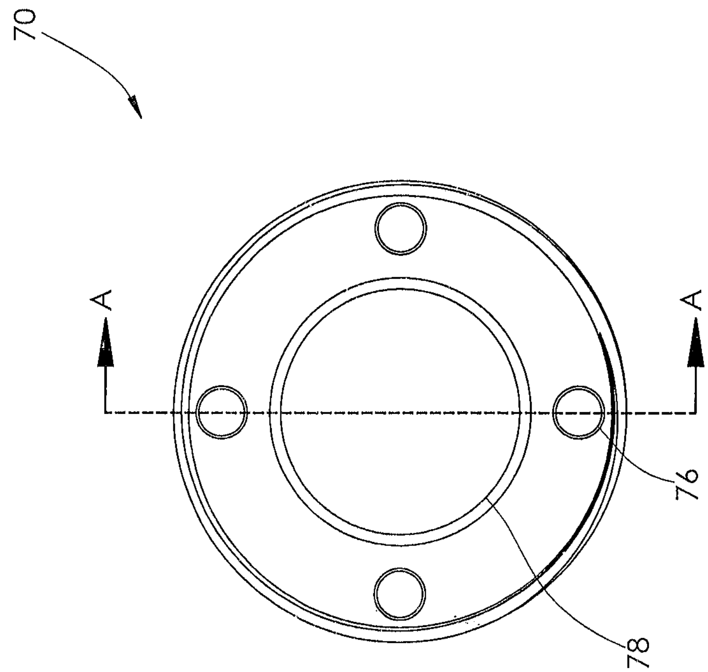
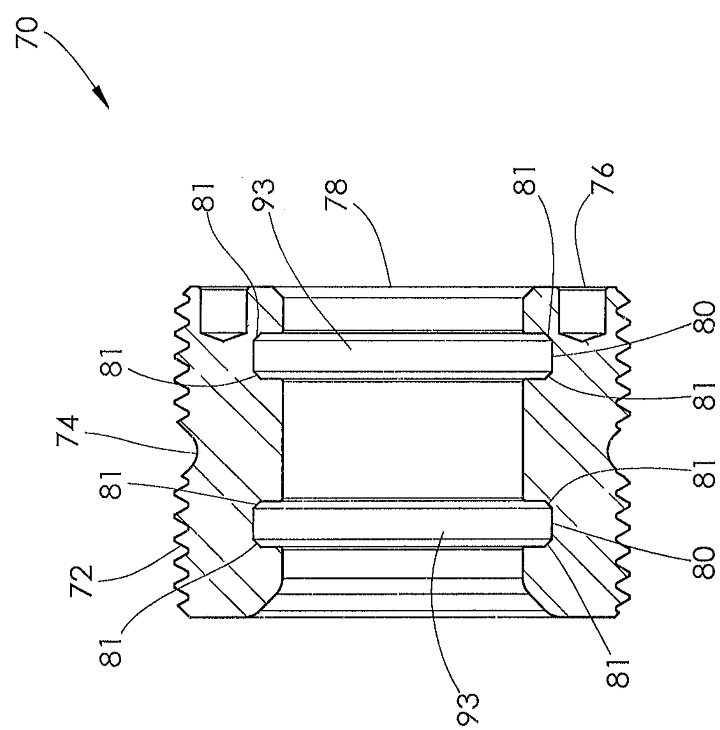


Figure 6A



SECTION A-A

Figure 6B

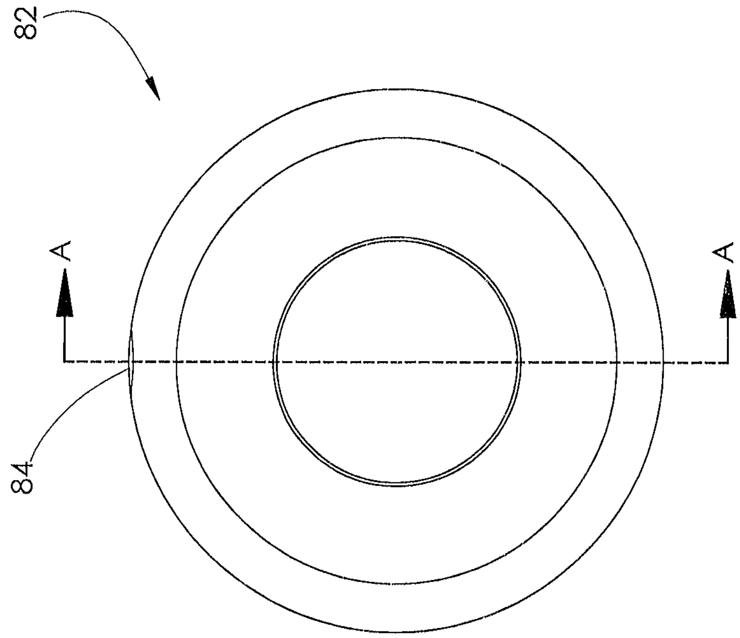


Figure 7A

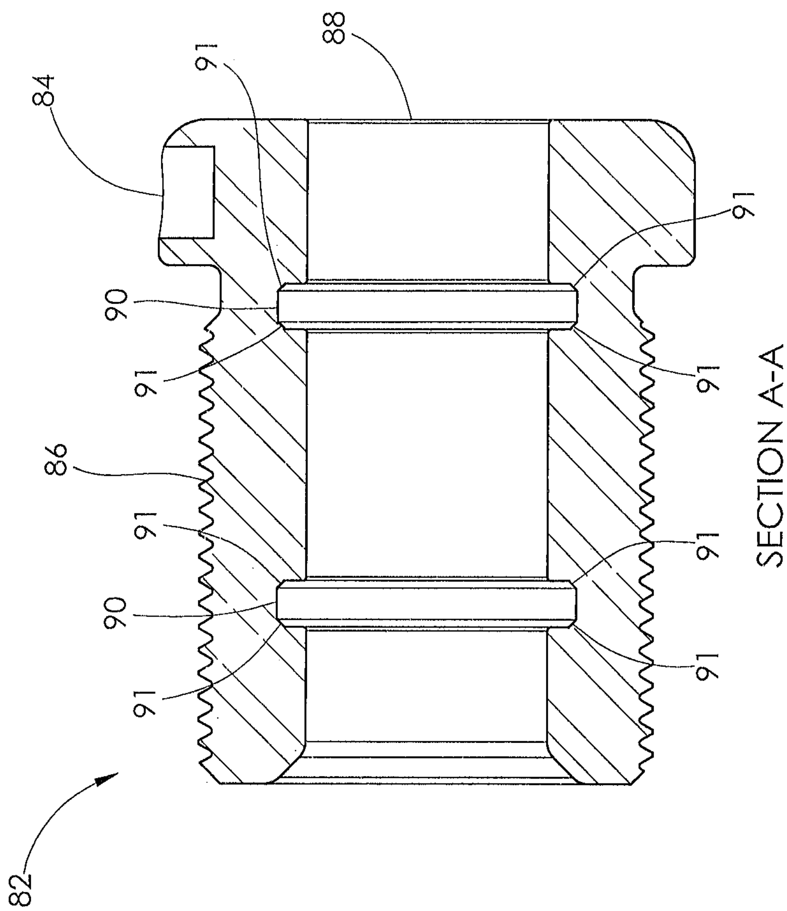


Figure 7B

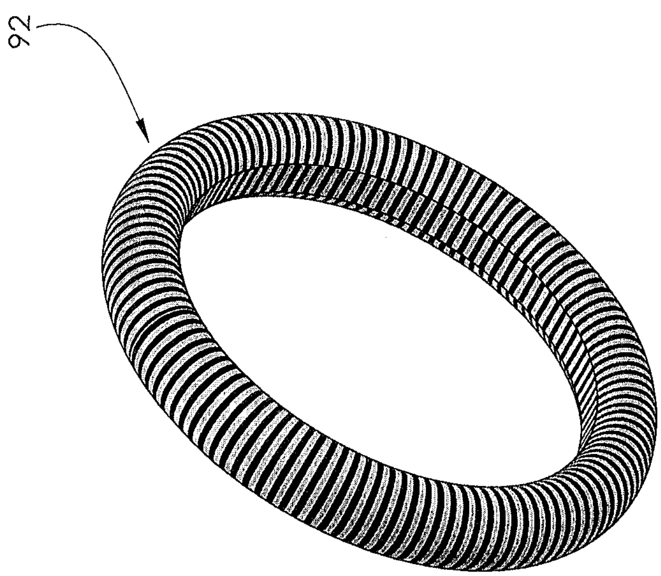


Figure 8

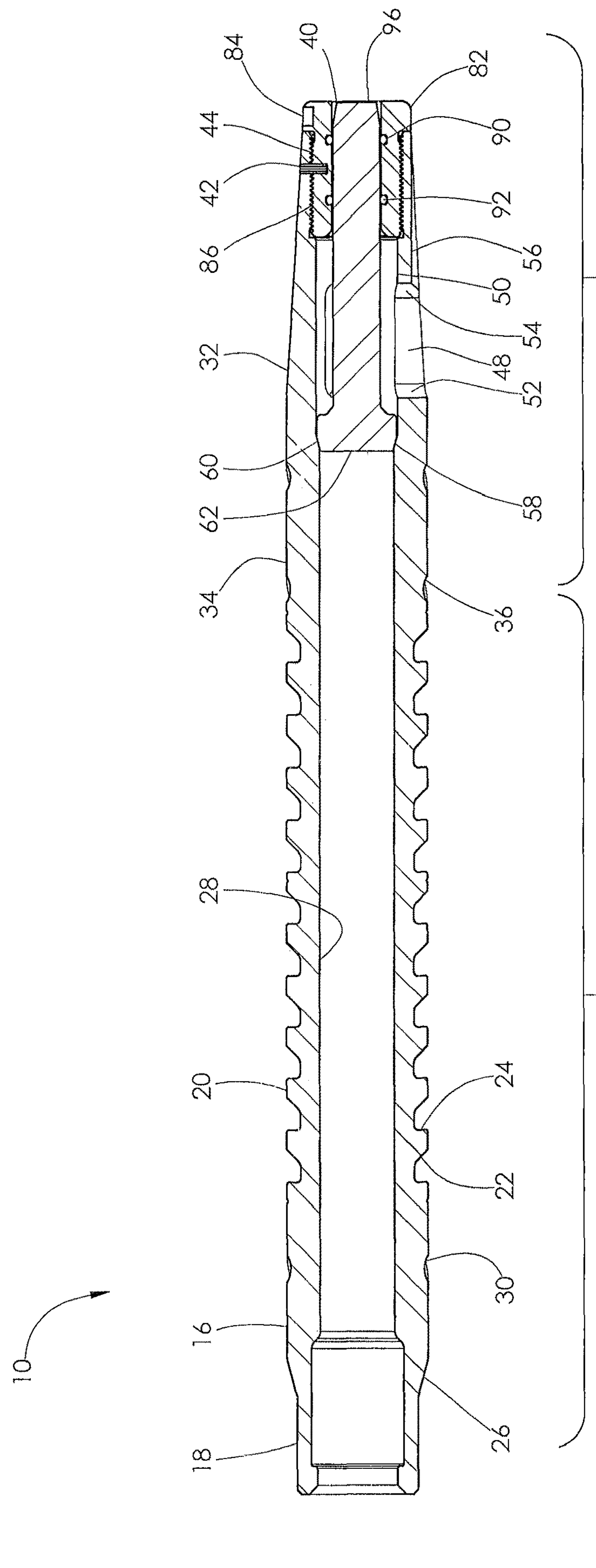

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Figure 9

PLUNGER LIFT SYSTEM

BACKGROUND

1. Field of the Invention

The present application generally relates to oil and gas production operations, and more particularly, to gas-lift plunger devices for restoring production to wells by lifting production fluids to the surface.

2. Description of Related Art

Presently, gas lift plunger devices have been in use for many decades and have a long history of development. The goal of these devices is to restore production in wells by using the gas pressure in the well to lift the production fluids to the surface. The plunger must be able to reach the bottom of the well and successfully build up pressure to start production of a well. As the plunger descends into the well, the fluid must be able to flow through the plunger. Once the plunger reaches the desired location, the push rod inside of the plunger is triggered to close a valve, thereby allowing the gas pressure to build up and lift the fluids to the surface. Multiple variations have been made over the years to increase productivity of these systems. One focus has been on controlling the volume of the fluid flowing through the plunger while the plunger descends. Another focus has been on setting the push rod and sealing the system.

While multiple improvements have been made throughout the years to improve these systems, not all of them are cost effective or are long lasting, and many shortcomings remain.

DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the application are set forth in the appended claims. However, the application itself, as well as a preferred mode of use, and further objectives and advantages thereof, will best be understood by reference to the following detailed description when read in conjunction with the accompanying drawings, wherein:

FIG. **1** is a longitudinal cross-sectional view of a plunger lift system according to a preferred embodiment of the present application;

FIG. **2**A is a side view of the plunger lift system of FIG. **1**, shown with the valve stem assembly removed;

FIG. **2**B is an end view of the plunger lift system of FIG. **2**A;

FIG. **2**C is a longitudinal cross-sectional view of the plunger lift system of FIG. **2**A taken at A-A of FIG. **2**B;

FIG. **3** is an exploded view of a valve stem assembly of the plunger lift system of FIG. **1**;

FIG. **4**A is an end view of a valve stem of the valve stem assembly of FIG. **3**;

FIG. **4**B is a side view of the valve stem of FIG. **4**A;

FIG. **5**A is an end view of an end cap of the valve stem assembly of FIG. **3**;

FIG. **5**B is a longitudinal cross-sectional view of the end cap of FIG. **5**A taken at A-A of FIG. **5**A;

FIG. **6**A is an end view of a clutch system of the valve stem assembly of FIG. **3**;

FIG. **6**B is a longitudinal cross-sectional view of the clutch system of FIG. **6**A taken at A-A of FIG. **6**A;

FIG. **7**A is a side view of an end cap of a valve stem assembly according to an alternative embodiment of the present application;

FIG. **7**B is a longitudinal cross-sectional view of the end cap of FIG. **7**A taken at A-A of FIG. **7**A;

FIG. **8** is a perspective view of a canted coil spring of the valve stem assembly of FIG. **3**; and

FIG. **9** is a longitudinal cross-sectional view of a plunger lift system according to an alternative embodiment of the present application.

While the method and device of the present application are susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific embodiments is not intended to limit the invention to the particular embodiment disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the present application as defined by the appended claims.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Illustrative embodiments of a plunger lift system according to the present application are provided below. It will of course be appreciated that in the development of any actual embodiment, numerous implementation-specific decisions will be made to achieve the developer's specific goals, such as compliance with assembly-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

Referring to FIG. **1** and FIGS. **2**A through **2**C in the drawings, a plunger lift system **10** according to the preferred embodiment of the present application is illustrated. Plunger **10** is preferably a continuous piece of material with two subsections, a plunger section **12**, and a rotary bypass valve assembly **14**. Plunger section **12** includes a plunger body **16**, an upper end **18**, outer rings **20**, a sloped surface **22**, a ring underside **24**, a tapered portion **26**, a central bore **28**, and one or more helical grooves **30**. Outer rings **20** are preferably a series of concentric rings around plunger section **12** that provide a seal against a well casing and reduce friction as plunger **10** descends or ascends inside a well bore. Sloped surface **22** on upper side of each ring facilitates ascent by reducing friction due to turbulence of the fluid inside of the well. Underside **24** of the outer rings **20** may be configured to serve a purpose, such as minimizing drag, improving sealing, providing a flushing action upon descent, etc. These alternative uses of underside **24** may be designed to meet a particular need of the well in which plunger **10** will be used. In alternative embodiments, outer rings **20** may be formed as a continuous helix instead of concentric rings, for example. As seen in FIG. **2**A, helical grooves **30** extend helically around plunger body **16**. Grooves **30** reduce drag and friction caused by turbulent fluids on plunger **10** inside of the well bore by causing plunger **10** to rotate while descending.

Rotary bypass valve assembly **14** includes a valve cage **32**, a valve cage body **34**, valve cage helical grooves **36**, an end cap **38**, a bore **40**, one or more roll pins **42**, threads **44**, one or more sockets **46**, one or more bypass ports **48**, a cylindrical bore **50**, a seat **58**, a chamfered perimeter of stem head **60**, an enlarged valve stem head **62**, a clutch assembly **64**, a valve stem **94**, and a valve stem lower end **96**. Each port **48** preferably includes a lower rounded end **52**, an upper rounded end **54**, and a ramp **56**. Body **34** of valve cage **32** is preferably continuously connected with the lower end of plunger body **16**, such that plunger **10** preferably forms one continuous piece of material. Body **34** of valve cage **32** includes helical grooves **36**, similar to helical grooves **30** on plunger body **16**, to assist with reducing friction and drag on plunger **10**, while plunger **10** is in the well bore. End cap **38** may be threaded into the lower end of the valve cage **32** at threads **44**. Once end cap **38** has been threaded into place, end cap **38** can be secured with set screws or roll pins **42**. One or more sockets **46** for removing or tightening end cap **38** with a spanner wrench or other appropriate tool (not shown) are disposed in the outer surface of end cap **38**. It is preferred that end cap **38** be tightened to a selected torque to prevent end cap **38** from coming undone while plunger **10** is in use. Valve cage **32** includes multiple bypass ports **48** disposed at equal radial intervals around valve cage **32**. The radius of valve cage **32** is the same as body **34** on one end while smaller on the end where end cap **38** is attached. This angled slope in valve cage **32** reduces drag and turbulence on plunger **10** when it is inserted to a well.

FIGS. **1** and **2**C illustrate cross-sectional views of plunger **10**. These views show sealing rings **20** disposed along the axis of plunger **10**. Shortened tapered portion **26** at upper end **18** of plunger body **16** permits plunger **10** to retain the full diameter of plunger body **16** over a maximum portion, preferably at least 70%, of the length of plunger body **16**. By maintaining this diameter, tapered portion **26** improves the sealing performance as plunger **10** rises within the well bore and lifts the fluids inside of the well bore. Plunger body **16** is preferably hollow with cylindrical bore **28** to permit the flow of fluid inside of plunger **10**, while plunger **10** descends into the well bore. During descent, fluid flow enters the lower end of plunger **10** through bypass ports **48** and cylindrical bore **50** in valve cage **32**, and flows through cylindrical bore **28** of plunger body **16**.

As shown in the cross-sectional view of FIG. **1**, bypass valve assembly **14** includes valve stem **94** disposed within bore **40** of end cap **38**, clutch assembly **64** encircling and operably associated with valve stem **94**, and elongated bypass port **48**. Although three such equally spaced ports **48** are preferred, the number of ports **48** may be varied in alternative embodiments. Bypass ports **48** facilitate the flow of fluids during descent of plunger **10** by allowing fluid to flow into plunger **10** through bypass ports **48** up into bore **28**. Bypass ports **48** relieved in valve cage **32** reduces the turbulence of the fluid and increases the stability of plunger **10** while inside the well bore. Valve stem **94** includes enlarged valve stem head **62** with chamfered perimeter **60**, which is configured to mate with seat **58** formed in the lower end of bore **28**. This configuration provides a poppet-type valve to regulate the flow of fluid through plunger **10**. Once plunger **10** reaches the bottom of the well bore (or a selected location within the well bore), the inertia of plunger **10** hitting the well bottom will overcome the spring force of clutch assembly **64**, enabling valve stem **94** to move upward through bore **50** in bypass valve cage **32** and against seat **58** in plunger body **16** to seal bypass valve assembly **14**. This poppet valve configuration seals bypass valve assembly **14**, thereby stopping the flow of fluid through plunger **10**. Thus sealed, bypass plunger **10** functions like a piston, allowing the gas pressure in the well to lift bypass plunger **10** upward, carrying accumulated fluids above plunger **10** to the wells surface.

Valve stem **94** is preferred made of type 174 heat treated stainless steel. Clutch assembly **64** is preferably made of type 174 steel, 4140 steel, 416 steal, or similar material. The remaining components, including plunger body **16**, valve cage **32**, and end cap **38** are preferably made of 4140 heat treated alloy steel. While particular types of steel are stated in this application, it will be appreciated that the various components of plunger **10** may be fabricated from any similar type of heat treated steel or similar material. These materials are readily available as solid "rounds" in a variety of diameters, as is well known in the art.

Continuing with reference to FIGS. **2**A through **2**C in the drawings, bypass valve cage **32** includes at least one bypass port **48**. Each bypass port **48** is an elongated slot cut through the wall of body **34** of valve cage **32** and includes lower rounded end **52** and upper rounded end **54**. Ports **48** are located at equal distances from each other around valve cage **32**. In addition, both lower end **52** and upper end **54** of each port **48** may be cut at selected angles into cage **32** to reach bore **50**. This relief of lower ends **52** and upper ends **54** of ports **48** facilitates the flow of fluid through ports **48** as bypass plunger **10** descends down the well bore. A ramp **56** may be disposed adjacent each rounded end **54** of each port **48** to further smooth the path for fluid flow at lower end **54** of each port **48**. It is preferred that each ramp **56** be substantially parallel with the longitudinal axis of valve cage **32**. The surface of each ramp **56** may be flat or curved. In alternate embodiments, lower end **52** and upper end **54** may be cut at similar angles or differing angles to better facilitate the descent of plunger **10** into the well bore, so as to decrease the turbulence and friction forces acting upon plunger **10**.

Referring now also to FIG. **3** in the drawings, valve cage **32**, valve stem **94**, clutch assembly **64**, and end cap **38** are shown in an exploded view. Valve stem **94** is operably associated with clutch assembly **64**. Clutch assembly **64** is releasably connected into valve cage **32** by threading threads **72** onto threads **44** of valve cage **32**. Clutch assembly **64** maintains valve stem **94** in an extended, open-valve position during the descent of bypass plunger **10**; and maintains valve stem **94** in a retracted, closed-valve position during the ascent of bypass plunger **10**. Clutch assembly **64** includes a clutch bobbin **70** and least one canted coil spring **92**. Each canted coil spring **92** is held inside an interior annular race **93**. Clutch assembly **64** is threaded into valve cage **32** and is held in place by end cap **38**.

Referring now also to FIGS. **4**A and **4**B in the drawings, valve stem **94** is illustrated. Valve stem **94** includes chamfered perimeter **60**, stem head **62**, and lower end **96**. Valve stem **94** preferably forms a straight smooth cylindrical shaft **95**. Other plunger systems use valve stems that have high friction, protrusions, upsets, and/or surface treatments along the length of the shaft to keep the valve stem from going up the plunger before hitting the bottom of the well bore. However, valve stem **94** of the present application does not need those features, as clutch assembly **64** successfully maintains the position of valve stem **94**, until plunger **10** comes into contact with the bottom of the well bore. Because shaft **95** is smooth and straight, the friction force applied by the fluid in the well bore is decreased, which allows plunger **10** to descend at a faster rate with less turbulence. In addition, straight smooth shaft **95** allows valve stem **94** to be more easily manufactured, and allows clutch assembly **64** to function more efficiently.

Referring now also to FIGS. **5**A and **5**B in the drawings, end cap **38** is illustrated. End cap **38** includes sockets **46**, threads **66**, and bore **68**. End cap **38** is connected to valve cage **32** by threads **66** and is preferably secured in place by roll pin **42**. Bore **68** runs through the center axis of end cap **38** to allow end cap **38** to be inserted over valve stem **94**.

Bore **68** is smooth to allow valve stem **94** to slide inside of bore **68** with limited friction force preventing movement of valve stem **94**.

Referring now also to FIGS. **6**A and **6**B in the drawings, clutch bobbin **70** is illustrated. Clutch bobbin **70** includes external threads **72**, roll pin groove **74**, sockets **76**, bore **78**, and one or more internal annular races **80**, each race **80** being configured to receive and secure a canted coil spring **92**. Clutch bobbin **70** is inserted over valve stem **94** first and is threaded into valve cage **32** via threads **72**. Clutch bobbin **70** includes one or more sockets **76** located at selected intervals along the circumference of a front face of clutch bobbin **70**, which may be used with a spanner or other tool to advance clutch bobbin **70** into valve cage **32** and tighten clutch bobbin **70** in place. In the preferred embodiment, four sockets **76** are used; however, it will be appreciated fewer or more sockets **76** may be used. Clutch bobbin **70** may include one or more roll pin grooves **74** to receive roll pins **42**. By utilizing this configuration for clutch bobbin **70**, no window in the side of valve cage **32** is necessary to install clutch bobbin **70**.

Annular races **80** extend radially outward from bore **78** and selectively sized and configured to receive and retain canted coil springs **92**. Canted coil springs are designed to take side loads. The use of canted coil springs **92** in clutch assembly **64** is unique to plunger lift systems and provides a unique tension force against valve stem **94**. Although it is preferred that clutch bobbin **70** include two annular races **80** and two corresponding canted coil springs **92**, it will be appreciated that clutch bobbin **70** may have more or fewer annular races **80** and canted coil springs **92**. By locating canted coil springs **92** on the interior of clutch bobbin **70**, as opposed to the exterior of clutch bobbin **70**, canted coil springs **92** can be selectively and particularly sized, shaped, and configured to be the primary source of friction on valve stem **94**. Thus, canted coil springs **92** do not have to provide any force to keep a multi-piece clutch bobbin connected. Each annular race **80** preferably includes chamfered ends **81** on each side of each annular race **80**. Chamfered ends **81** prevent canted coil springs **92** from spinning while valve stem **94** moves within valve cage **32**.

Referring now to FIGS. **7**A and **7**B in the drawings, an alternative embodiment of clutch bobbin **70** and end cap **38** is illustrated. In this embodiment, clutch bobbin **70** and end cap **38** are replaced by a clutch bobbin **82** having an integral end cap. Clutch bobbin **82** includes one or more sockets **84**, external threads **86**, a bore **88**, and one or more interior annular races **90**. Annual races **90** are sized and shaped to receive and retain canted coil springs **92**. Although two annular races have been shown, it will be appreciated that more or fewer annular races **90** may be utilized. Threads **86** allow clutch bobbin **82** to be installed inside of valve cage **32**. Like socket **46** in end cap **38**, socket **84** is designed to accommodate a spanner wrench or other tool for easily installing or uninstalling clutch bobbin **82** into valve cage **32**. As with clutch bobbin **70**, each annular race **90** preferably includes chamfered ends **91** on each side of each annular race **90**. Chamfered ends **91** prevent canted coil springs **92** from spinning while valve stem **94** moves within valve cage **32**. This one-piece configuration allows the distance between canted coil springs **92** to be increased, which leads to additional stability of plunger **10**.

Referring now also to FIG. **8** in the drawings, canted coil spring **92** is illustrated. Although the individual coils are not depicted, canted coil spring **92** is a special coiled spring connected end-to-end in the shape of a circle. Canted coil Spring **92** exerts a near constant radially inward force against valve stem **94**. This force is not decreased even if exposed to high temperatures. This inward force on valve stem **94** prevents valve stem **94** from moving axially, until the inward force is exceeded, such as by the inertial force created when the plunger hits the bottom of the well bore. The large number of coils which create canted coil spring **92** compensate for any misalignment or irregularities in canted coil spring **92** from continued use. Because the large number of coils in canted coil spring **92** can compensate for irregularities in the structure of canted coil spring **92**, canted coil spring **92** will have an increased durability. This increased durability extends the time that canted coil spring **92** can be used without replacement, thereby extending the life of clutch bobbins **70**, **82**. Canted coil spring **92** is preferably made from type 174 stainless steel, but may be made with any type of heat resistant material, such as stainless steel, zirconium copper, or beryllium copper. Canted coil spring **92** may be otherwise treated with conventional methods and materials for improved resistance to corrosive materials, further extending the life of canted coil spring **92**, clutch bobbin **70**, **82**, and plunger **10**. It is further appreciated that while canted coil springs **92** are used in the present application, alternative embodiments can exist where coiled springs which are not canted are used instead of canted coil springs **92**.

Referring now also to FIG. **9** in the drawings, plunger **10** having clutch bobbin **82** is illustrated. As is shown, clutch bobbin **82** is held in place within valve cage **32** by roll pin **42**. Valve stem **94** is shown in the retracted position, i.e., after plunger **10** has encountered the bottom of the well bore.

It is apparent that a system with significant advantages has been described and illustrated. The particular embodiments disclosed above are illustrative only, as the embodiments may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. It is therefore evident that the particular embodiments disclosed above may be altered or modified, and all such variations are considered within the scope and spirit of the application. Accordingly, the protection sought herein is as set forth in the description. Although the present embodiments are shown above, they are not limited to just these embodiments, but are amenable to various changes and modifications without departing from the spirit thereof.

What is claimed is:

1. A plunger lift system, comprising:

a plunger body having a central bore; and

a bypass valve assembly disposed at a lower end of the plunger body, the bypass valve assembly comprising:

a valve cage;

a valve stem disposed at least partially within the valve cage;

a unibody clutch bobbin carried by the valve cage and being operably associated with the valve stem, wherein the clutch bobbin comprises external threads for engagement with the valve cage and at least one socket disposed on a lower face of the clutch bobbin for installing and uninstalling the clutch bobbin into the valve cage;

at least one canted coil spring disposed at least partially within the clutch bobbin for controlling movement of the valve stem;

an end cap coupled to the valve cage and extending partially into the valve cage, the end cap securing the clutch bobbin within the valve cage.

2. The plunger lift system of claim **1**, wherein the bypass valve assembly further comprises:

an internal annular race for receiving each canted coil spring.

3. The plunger lift system of claim **2**, wherein the bypass valve assembly further comprises:

chamfered ends on each side of each internal annular race to prevent the canted coil spring from spinning as the valve stem moves within the valve cage.

4. The plunger lift system of claim **1**, wherein the clutch bobbin comprises a cylindrical bore running axially through the center of the clutch bobbin.

5. The plunger lift system of claim **4**, wherein the clutch bobbin further comprises:

at least one socket disposed on a lower face of the clutch bobbin for installing and uninstalling the clutch bobbin into the valve cage.

6. The plunger lift system of claim **1**, wherein the valve stem comprises:

an enlarged stem head;

a chamfered perimeter around the stem head; and

a straight shaft portion having a smooth surface, the shaft portion extending down from the stem head.

7. The plunger lift system of claim **6**, wherein the plunger body comprises:

an internal seat formed in a bore disposed within the valve cage, the internal seat being configured to receive the enlarged stem head so as to form a seal between the valve stem and the central bore.

8. The plunger lift system of claim **1**, wherein the valve stem is operable between an extended open position in which fluid may flow through the valve cage into the central bore, and a retracted closed position, in which the flow of fluid through the valve cage into the central bore is prevented.

9. The plunger lift system of claim **1**, wherein the plunger body comprises:

a series of concentric outer rings, each outer ring having at least one sloped surface; and

a tapered portion disposed near the upper end of the plunger body.

10. The plunger lift system of claim **1**, wherein the plunger body comprises:

at least one helical groove located on an exterior surface of the plunger body.

11. The plunger lift system of claim **1**, wherein the plunger body further comprises:

a bore running through the plunger body.

12. The plunger lift system of claim **1**, wherein the bypass valve assembly further comprises:

one or more ports located along the valve cage to allow fluids to flow into the valve cage.

13. The plunger lift system of claim **12**, wherein the bypass valve assembly further comprises:

a ramp associated with each port to facilitate fluid flow into the valve cage.

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