A plunger for a plunger lift system of an oil and/or gas well for use in lifting a fluid out of a well bore. The plunger includes a generally cylindrical elongated plunger body with an upper and a lower end, wherein the lower end includes a thermoset tubular seal member, preferably a composite seal member adapted to slidingly contact the well bore and aid in the extraction of fluids from the well during plunger lift.
WELL PLUNGER AND PLUNGER SEAL
FOR A PLUNGER LIFT PUMPING SYSTEM

FIELD OF THE INVENTION

[0001] The present invention relates to a plunger for a plunger lift system of an oil and/or gas well for use in lifting a fluid out of a well bore. The plunger includes a generally cylindrical elongated plunger body with an upper and a lower end, wherein the lower end includes a thermoset tubular seal member, preferably a composite seal member adapted to slidingly contact the well bore and aid in the extraction of fluids from the well during plunger lift.

BACKGROUND OF THE INVENTION

[0002] Well fluid such as oil and gas at times do not have sufficient gas pressure and volume activity to continuously expel fluids from the well without mechanical devices or external assistance. In some cases, well fluid may be recovered by the use of a plunger, sometimes also referred to as a gas lift plunger, piston, or rabbit. Plungers are generally freely movable within tubing present in the well and travel between the top and bottom of the well through the tubing. Well fluids from an oil or gas bearing formation seep into the tubing preferably below the plunger and accumulate, with the plunger being at rest at the bottom of the well above a tube end. The accumulated fluids are lifted by the plunger to an output flow line at the surface.

[0003] Operation of the plunger is typically controlled by the opening and closing of a valve located in the output flow line. With the plunger at the bottom of well tubing resting against a member such as a tube end or seating nipple, and with the well valve closed, pressure in the geological formation will build up over a period of time. A timing mechanism opens the valve after a predetermined time lapse. This establishes a pressure differential across the plunger and greater pressure beneath the plunger drives the plunger upwardly through the tubing. Upward movement of the plunger pulls well fluid up the tubing and outwardly through the output flow line. When a plunger reaches the top of the tubing and after fluid has been pulled from the well, the well valve is
closed. Pressure across the plunger then equalizes, and the plunger falls by gravity to
the bottom of the well in the tubing. The process is then repeated.

[0004] Various types of plungers have been used, such as valve-type plungers.
Valve-type plungers are generally provided with a passageway therethrough which is
opened and closed by a valve. During upward movement of the plunger, the valve is
closed so that the interior of the tubing above the plunger is substantially sealed from
the interior of the tubing below the plunger. This maintains the gas differential
necessary for lifting. During downward movement of the plunger, the valve is open to
permit well fluid to flow substantially freely through the passageway. Other valve type
plungers include circumferentially, radially, expandable sections which are expanded
into contact with the well tubing during upward movement of the plunger, and are
retracted, i.e., a valve is opened, during downward movement of a plunger. Valve type
plungers are generally complex and can be costly to manufacture. Reliability of the
moving parts cannot be guaranteed.

[0005] Valveless-type plungers also exist in many different forms. Valveless
plungers are generally used in low production wells where it is not necessary to quickly
return the plunger to the bottom of the well. Valveless plungers typically have a rate of
descent which is slower than valve-type plungers, as there is no bypass valve
passageway to open during descent.

[0006] Examples of various plungers are set forth in U.S. Patent Nos. 3,179,022;
3,424,066; 3,953,155; 4,007,784; 4,030,858; 4,410,300; 4,502,843; 4,531,891;
4,889,473; 4,898,235; 5,427,504; 5,868,554; 6,045,335; 6,200,103; 6,554,580;
6,669,449; 6,725,916; 6,746,213; U.S. Publication Nos. 2003/0141051; 2004/0165992;
2006/0185853; and PCT Publication No. WO 02/070339.

[0007] Various problems can be encountered when utilizing valveless plungers,
particularly with regard to dimensions of the annular clearance gap within the well
tubing. There should be a sufficiently tight fit of the plunger within the tubing to afford a
sufficiently effective seal during lifting. However, clearance must be wide enough to
allow descent at a rate which is not too slow to be practical. Too loose a fit sacrifices
lifting efficiency during lifting and too tight a fit sacrifices descent rate. There is a need for a valveless plunger which affords enhanced lifting capability, yet descends at a practical rate.

[0008] An additional problem encountered is the maintenance of sealing tolerances over extended periods of use of the plunger. The location of the plunger within the well necessitates the plunger be resistant to the atmosphere of the well and fluids contained therein. An additional problem is that the plunger must be resistant to frictional wear against the interior sidewall of the well tubing.

SUMMARY OF THE INVENTION

[0009] It is, therefore, an object of the present invention to provide a plunger for a gas and/or oil well, which provides efficient lifting capability while still allowing descent at a practical rate. Still another object of the invention is to provide a plunger that is economical to manufacture and can be produced having controlled tolerances.

[0010] Yet another object of the present invention is to provide a plunger that is resistant to the environment encountered in the well and is, therefore, durable.

[0011] Another object of the present invention is to provide a plunger that is wear resistant and substantially maintains sealing tolerances over an extended period of use.

[0012] Yet another object of the present invention is to provide a plunger having a surface coating that provides a low friction surface that enables the plunger to smoothly travel within tubes of the well. The surface coating also extends the life of the plunger and prevents the formation of rust thereon.

[0013] Another object of the present invention is to provide a thermoset seal member, preferably a composite seal member for a plunger that is lightweight and has a high strength-to-weight ratio. The seal member is chemical, moisture and oil resistant. The seal member is dimensioned such that a desirable seal is maintained between the seal member and well tubing in order to maintain pressure and keep fluid below the shaft during lifting of the fluid.
[0014] Still another object of the present invention is to provide a plunger that can be easily disassembled, thereby allowing the seal member to be replaced as desired, thereby extending the life of the plunger.

[0015] In one aspect of the current invention, a plunger for a plunger lift pumping system is disclosed, comprising an elongated cylindrical body comprising an upper segment connected to a lower segment by a fastener wherein the upper segment includes a plurality of circumferential ridges and a plurality of circumferential grooves on an exterior of the body, wherein the lower segment includes an end stop and a seal member carrier located above the end stop and having an outer diameter less than an outer diameter of the end stop; and a seal member, wherein the seal member is substantially cylindrical and has an aperture extending through a longitudinal axis of the seal member, wherein the seal member carrier extends through the seal member aperture, wherein an outer diameter of a portion of the end stop and a portion of the upper segment are each greater than an inner diameter of the seal member to maintain the seal member operatively connected to the body, and wherein the seal member comprises a thermoset resin.

[0016] In a second aspect of the present invention, a plunger for a plunger lift pumping system is disclosed, comprising an elongated cylindrical body comprising an upper segment and a lower segment, a tubular seal member disposed on the body above an end stop of the upper segment, wherein an outer diameter of a portion of the end stop and a portion of the upper segment are greater than an inner diameter of the seal member to maintain the seal member operatively connected to the body, wherein a seal member carrier extends through the inner diameter of the seal member, wherein the seal member carrier has a maximum outer diameter which is less than the inner diameter of the seal member and a clearance is provided between the seal member and seal member carrier, wherein the seal member comprises a thermoset resin optionally including fibers, wherein the body has a chrome-containing surface coating having a Rockwell hardness greater than or equal to 60.
In a third aspect of the present invention, a seal member for a plunger for a plunger lift pumping system is disclosed, comprising an elongated tubular body having a cylindrical inner diameter, wherein the body has a substantially cylindrical outer diameter having chamfered ends, wherein the chamfered ends each have a length that independently range from about 0.25 to about 1 inch measured along a longitudinal axis of the seal member, wherein each chamfered end tapers individually at an angle of from about 1° to about 20° measured parallel to the longitudinal axis of the seal member, and wherein the seal member comprises a thermoset resin.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood and other features and advantages will become apparent by reading the detailed description of the invention, taken together with the drawings, wherein:

FIG. 1 is a side elevational view of a pressure operated plunger according to one embodiment of the present invention including a composite seal member;

FIG. 2 is a schematic representation of an embodiment of a well installation for producing well fluids from a subterranean formation, wherein a plunger according to the present invention is shown located within tubing of the well;

FIG. 3 is a cross-sectional elevational view of the plunger illustrated in FIG. 1 through line 3-3;

FIG. 4 is a side elevational view of one embodiment of a seal member of the present invention;

FIG. 5 is a side elevational view of a lower segment of one embodiment of a plunger of the present invention; and

FIG. 6 is a side elevational view of an upper segment of one embodiment of a plunger of the present invention.
DETAILED DESCRIPTION OF THE INVENTION

[0019] This description of preferred embodiments is to be read in connection with the accompanying drawings, which are part of the entire written description of this invention. In the description, corresponding reference numbers are used throughout to identify the same or functionally similar elements. Relative terms such as "horizontal", "vertical", "up", "down", "top" and "bottom" as well as derivatives thereof (e.g., "horizontally", "downwardly", "upwardly", etc.) should be construed to refer to the orientation as then described or as shown in the drawing figure under discussion. These relative terms are for convenience of description and are not intended to require a particular orientation unless specifically stated as such. Terms including "inwardly" versus "outwardly", "longitudinal" versus "lateral", and the like are to be interpreted relative to one another or relative to an axis of elongation, or an axis or center of rotation, as appropriate. Terms concerning attachments, couplings and the like, such as "connected" and "interconnected", refer to a relationship wherein structures are secured or attached to one another either directly or indirectly through intervening structures, as well as both movable or rigid attachments or relationships, unless expressly described otherwise. The term "operatively connected" is such an attachment, coupling or connection that allows the pertinent structures to operate as intended by virtue of that relationship.

[0020] Referring now to FIG. 1, there is illustrated one embodiment of a plunger 10 for a plunger lift system of an oil or gas well or both. Such as shown in FIG. 2, plunger 10 is inserted in tubing 120 of a well 110 and is freely movable between the top and a lower portion of the tubing, above a stop when present. The pressure of the subterranean fluid within the well causes upward movement of the plunger, the cycling of which is controlled by the plunger lift system.

[0021] Plunger 10 has an elongated body 12 that is generally tubular or cylindrical, having a first or top end 14 and a second or bottom end 16. A seal member 60 is operatively connected to the body 12 between the top end 14 and bottom end 16, preferably closer to bottom end 16, such as explained further hereinbelow. The plunger body 12 and seal member 60 are sized to fit into a selected size of tubing string with a
selected clearance to allow fluid to flow upward, but preferably not around the plunger, as desired by the plunger lift system. By way of example, common tube sizes utilized in the industry are tubes having an outer diameter of 2.375 inches and an inner diameter of 1.995 inches, and tubes having an inner diameter of 1.610 inches. Other common well tubes having outer diameters of 1.25, 1.5, 2.0625, 2.875 and 3.5 inches to which the plunger 10 can be adapted to be utilized therein.

[0022] Top end 14 includes a fishing neck 22 that has an external size and shape that corresponds to a conventional oil and gas well plunger fishing neck and, thus, allows the plunger 10 to be retrieved mechanically from within the well by a fishing tool when desired or necessary. The fishing neck preferably includes a head 24 and a neck 26, lower on the body 12 when compared to head 24. Head 24 and neck 26 are preferably cylindrical, with neck 26 having an outer diameter smaller, preferably significantly smaller, than the head 24 to allow for connection to a fishing tool when retrieval is desired. The outer diameter of the head 24 and neck 26 can vary along a length thereof, if desired. When plunger 10 is adapted to be utilized in a 1.610 inch inner diameter well tube, head 24 preferably has an outer diameter including any surface coating of about 0.880 inch measured perpendicular to a longitudinal axis of the plunger, and a height of about 0.618 inch measured along the longitudinal axis of the plunger. In one embodiment, the upper most end of head 24 includes a chamfer such as at an angle of about 30°, over a length of about 0.15 inch. In one embodiment, neck 26 has a diameter of about 0.700 inch. The fishing neck 22 has a length that ranges generally from about 1 to about 3 inches and preferably is about 1.925 inches. When plunger 10 is adapted to be utilized in a 1.995 inch inner diameter well tube, head 24 preferably has a diameter including any surface coating of about 1.371 to about 1.372 inches, and a height measured along the longitudinal axis of the plunger of about 0.50 inch. In one embodiment, the upper most end of the head 24 includes a chamfer such as at an angle of about 30°, over a length of about 0.15 inch. In one embodiment, neck 26 has a diameter of about 1.185 inch. The fishing neck 22 for use in a 1.995 inch inner diameter well tube has a length that ranges generally from about 1.5 to about 3.5 inches and preferably about 2.5 inches.
[0023] Neck 26 terminates at, and is connected to collar 28 which has an outer diameter greater than head 24 and neck 26, with the collar 28 preferably constructed to have a close tolerance with the inner diameter of the well tube shaft into which plunger 10 is inserted. For example, when a well shaft has a 1.995 inch inner diameter, in one embodiment the collar 28 has an outer diameter of about 1.846 to about 1.857 inches, including any surface coating thereon; and when a 1.610 inch inner diameter well shaft is present, the collar 28 preferably has a diameter of about 1.496 to about 1.507 inches total, including any surface coating thereon.

[0024] The plunger body 10 includes at least one and preferably a plurality of longitudinally spaced ridges 30 and grooves 32. The ridges 33 and grooves 32 aid in bringing fluid out of the well. The number of ridges and grooves can vary. Likewise, the height, measured radially outward from a central longitudinal axis of the plunger 10 and width, measured along the longitudinal axis of the plunger 10, of each groove can vary. In a preferred embodiment, the height of each groove is substantially equal to the height of the collar 28. The total number of ridges can range generally from about 6 to about 14, and preferably from about 8 to about 12.

[0025] The total number of grooves can range generally from about 6 to about 14 and preferably from about 8 to about 12. In the embodiment illustrated in FIG. 1, the ridges include a substantially flat plateau that transitions into an angled region that leads to groove 32 which also has a substantially flat valley. In one embodiment the length of the flat portion of the ridge ranges from about 0.125 inch to about 0.500 inch, and is preferably about 0.250 inch. A distance from the end of one flat portion of a ridge to the end of another ridge measured across a groove 32 parallel to the longitudinal axis of the tube has a distance generally from about 0.125 inch to about 0.500 inch and is preferably about 0.375 inch. The longitudinal length of the valley ranges generally from about 0.0625 inch to about 0.50 inch and is preferably about 0.1875 inch. The angle created by an intersection of two inclines 34 located on either side of groove 32 ranges generally from about 20° to about 120° and preferably is about 60°.
[0026] In an embodiment where the plunger is to be utilized in a 1.610 inch inner diameter well tube, the length of the section including collar 28, ridges 30 and grooves 32 ranges generally from about 6 to about 10 inches and preferably is about 8.475 inches measured along the longitudinal axis of the plunger 10. In a further embodiment wherein the plunger is to be utilized in a 1.995 inch inner diameter well tube, the length of the section including collar 28, ridges 30 and grooves 32 ranges generally from about 8 to about 14 inches, and preferably is about 9.50 inches measured along the longitudinal axis of the plunger 10.

[0027] As indicated hereinabove, plunger 10 includes a top segment 18 and a lower segment 20, such as illustrated in FIG. 1. FIG. 6 illustrates a further view of upper segment 18 and FIG. 5 illustrates a further view of lower segment 20. The segments 18 and 20 are connected by a suitable fastener. In one embodiment, machined threads 36 are utilized to connect upper segment 18 to lower segment 20. In a preferred embodiment, to decrease the weight of plunger 10, body 12, preferably upper segment 18, is provided with a bore 36 that extends along the desired length of the upper segment 18. In one embodiment, the bore 36 extends the entire length of the ridges 30 and grooves 32, and can extend into collar 28. The diameter of the bore can vary. For example, in one embodiment, for a 1.610 inch inner diameter tube, the bore is generally from about 0 to about 1.0 inch and preferably about 0.937 inch in diameter measured perpendicular to the longitudinal axis of the tube. In one embodiment for a 1.995 inch inner diameter tube, the bore is generally from about 0 to about 1.20 inches and preferably 1.180 inches measured perpendicular to the longitudinal axis of the tube. As indicated, the bore can be absent to increase plunger strength and weight.

[0028] Lower segment 20 of plunger 10 includes an upper end which can be fastened to upper segment 18, such as utilizing a fastener, preferably threads, as explained hereinabove. In the embodiment illustrated in FIG. 1, upper end of lower segment 20 includes threads 36 which are mateably received within threads 36 of upper segment 18. The upper end of lower segment 20 includes a relief 38 located below the threads present which can increase the strength of the shaft. The length of the relief
can vary and ranges from about 0.06 to about 1.0 inch, and preferably from about 0.120 to about 0.505 inch measured along the longitudinal axis.

[0029] Lower segment 20 includes a seal member carrier 40 that is preferably cylindrical and has a lower end terminating at seat 42 of end stop 44. Seal member carrier 40 has an outer diameter which is less than or equal to the inner diameter of the seal member 60. In a preferred embodiment, a clearance 50 is provided between the outer diameter of carrier 40 and the inner diameter of seal member 60 to allow for a desired play between carrier 40 and seal member 60. Clearance 50 also aids in allowing seal member 60 to compensate for any irregularities within the well tube. Movement between the carrier 40 and seal member 60 due to the clearance also aids in preventing the plunger from getting stuck on collars that connect well tubes. Moreover, a clearance 50 between seal member 60 and seal member carrier 40 also allows fluid to flow therebetween when the plunger 10 is descending within the well tubing. The fastener connection between upper segment 18 and lower segment 20 allows for the ability to change a seal member 60 when desired, such as for example in order to utilize a seal member 60 having a larger or smaller diameter to increase or decrease the fit between seal member 60 and inner diameter of the well tubing. End stop 44 maintains seal member securely on plunger 10 as end stop 44 has an outer diameter greater than the inner diameter of seal member 60. The length of end stop 44 can vary, measured along a longitudinal axis of the plunger. That said, the seal member 60 can be located a distance measured along the longitudinal axis from the bottom of plunger 10, generally at the base of end stop 44, at a distance generally from about 0.125 to about 6 inches, desirably from about 0.5 to about 4 inches and preferably from about 1 to about 2 inches. In a preferred embodiment, the end stop has a longitudinal length measured along the longitudinal axis of generally from about 1 to about 2 inches, and preferably about 1.550 inches. It has been found that by locating the seal member 60 on the plunger 10 relatively close to the bottom end provides increased plunger lift.

[0030] In one embodiment, for a 1.610 inch inner diameter well tubing, the diameter of the end stop ranges generally from about 1.996 to about 1.506 inches, and preferably is about 1.501 inches including any surface coating thereon, measured perpendicular to
the longitudinal axis of the plunger. In an embodiment for a 1.995 inch inner diameter tubing, the diameter of the end stop ranges generally from about 1.846 to about 1.856 inches, and preferably is about 1.851 inches including any surface coating thereon, measured perpendicular to the longitudinal axis of the plunger.

[0031] In an important aspect of the present invention, plunger 10 includes seal member 60. Seal member 60 desirably extends outward a greater distance radially, i.e., perpendicular to the longitudinal axis of the plunger 10, than any component of the upper segment 18 and lower segment 20 of plunger 10 of the present invention in order to desirably form a seal between plunger 10 and the inner diameter of the well tubing, while providing a sliding fit within the well tubing. Seal member 60 is preferably a single-piece chamfered cylindrical tube having an inner diameter greater than the outer diameter of seal member carrier 40 and thus can be placed thereon prior to connecting lower segment 20 and upper segment 18 of plunger 10. In an alternative embodiment, the plurality of seal member 60 can be utilized on plunger 10. Seal member 60 preferably has a longitudinal length which aids in slidingly sealing plunger 10 within well tubing and preventing fluid from flowing around the outside of the composite seal member 60 during lifting of well fluids.

[0032] In one embodiment, seal member 60 has a central area 62 having an outer surface, preferably cylindrical, that is preferably parallel to the longitudinal axis of the plunger 10. One or more ends of seal member 60 include a chamfer or taper 64 over a length thereof, such as from about 0.25 to about 1 inch, and preferably about 0.50 inch. The angle of the taper can vary with respect to longitudinal axis and can range generally from about 1° to about 30°, desirably from about 4° to about 6°, and preferably about 5°.

[0033] In one embodiment, when plunger 10 is to be used in a 1.610 inch inner diameter well tube, seal member 60 preferably has a maximum outer diameter generally from about 1.501 to about 1.608 inches, and preferably 1.525 to about 1.530 inches. The inner diameter ranges generally from about 1.180 to about 1.250 inches, and preferably is about 1.230 inches. The seal carrier 40 has an outer diameter which is less than the inner diameter of the seal member 60 and generally ranges from about
1.210 to about 1.225, and preferably from about 1.215 to about 1.220. In one embodiment, when plunger 10 is to be used in a 1.995 inch inner diameter well tube, seal member 60 preferably has a maximum outer diameter generally from about 1.848 to about 1.995 inches, and preferably 1.885 to about 1.890 inches. The inner diameter ranges generally from about 1.50 to about 1.550 inches, and preferably is about 1.530 inches. The seal carrier 40 has an outer diameter which is less than the inner diameter of the seal member 60 and generally ranges from about 1.505 to about 1.515, and preferably from about 1.509 to about 1.511. Obviously, if no clearance is desired to be provided between the outer diameter of the seal carrier 40 and the inner diameter of seal member 60, the diameters are substantially equal with the seal member fitting snugly on the seal carrier 40.

[0034] The longitudinal length of seal member 60 measured in relation to a longitudinal axis of the plunger can vary in order to provide for a desired lifting capability within a well. The length can also vary depending upon the inner diameter of a well tube in which the seal member 60 will be utilized. The length of a seal member can range generally from about 0.5 to about 12 inches, desirably from about 2 to about 8 inches, and preferably from about 3 to about 6.5 inches. In an embodiment wherein plunger 10 is to be utilized in a 1.610 inch inner diameter well tube, seal member 60 preferably has a length of generally from about 3.985 to about 4.000 inches, and preferably from about 3.990 to about 3.995 inches. In an embodiment wherein plunger 10 is to be utilized in a 1.995 inch inner diameter well tube, seal member 60 preferably has a length of generally from about 5.985 to about 6.000 inches, and preferably from about 5.990 to about 5.995 inches.

[0035] Seal member 60 is preferably formed comprising a thermoset material having good mechanical strength and dimensional stability for extended use within a well. The seal member 60 is also preferably resistant to corrosion and chemicals or fluids encountered within the well. It is also desired that the seal member 60 has low moisture absorption and does not swell substantially when in contact with well fluids.
The seal members of the present invention are formed comprising a thermoset material, and most preferably the thermoset material comprising fiber reinforcement. The seal members are preferably free of metal and preferably free of rubber and are substantially non-elastic, in contrast to rubber seals utilized in the prior art. The seal member is also preferably free of spiral winding and preferably has substantially no loose fibers, when present, that extend from the main surface of the thermoset surface. A composite seal member is formed by impregnating fibers with a thermosetting resin, wherein the uncured composite is formed into a desired shape. Afterwards, heat, pressure and/or radiation are often used in order to cure the composite seal member into a set form. After thermosetting, a seal member can be machined, for example, if it is desired to further change one or more features of the seal member.

The thermoset resin suitable for use in the present invention can be cured utilizing one or more of heat, a chemical reaction, radiation, or other methods such as known to those of ordinary skill in the art. Preferred thermosetting resins are derived from a composition including at least one monomer including an aromatic group, such as a phenol group, melamine group, or the like. The thermoset resins after curing are crosslinked structures which cannot be melted and reshaped. Examples of synthetic thermoset resins include, but are not limited to, phenolic resins, melamine resins, silicone resins, urea-formaldehyde resins, thermosetting polyester resins and epoxy resins. Phenolic resin is preferred in one embodiment. As indicated hereinabove, in a preferred embodiment, the seal member 60 is a composite seal member formed by impregnating fibers with a thermoset resin.

Fibers suitable for use in the composite seal member of the present invention comprise one or more of natural and synthetic fibers. The fibers can be woven into a suitable fabric or can be assembled in a non-woven form such as through hydro-entanglement, or simply added to the resin in a random form prior to curing. Examples of suitable natural fibers which are either from plants or animals, include, but are not limited to, fibers derived from natural sources such as cotton, wood or wood pulp derived from trees, bushes and shrubs, abaca, alpaca, bamboo, cashmere, coconut
fiber, flax, hemp, jute, kenaf, mohair, silk, sisal, soybean fiber, wool, or the like. Synthetic fibers are well known in the art and formed from materials such as, but not limited to, thermoplastics including polyolefins, for example polyethylene and polypropylene, various polyamides, i.e., nylons, acetate, acrylate, acrylic, carbon, polyester, polyurethane, or the like. Additional fibers include materials such as glass, i.e., fiberglass. When woven, the materials comprising fibers can be paper, canvas, linen, and the like. Any number of woven or non-woven layers can be utilized in the formation in the composite seal member. In a preferred embodiment, one or more of canvas, linen, paper and wood pulp are utilized in the composite seal member of the present invention.

[0039] Synthetic thermosetting resins are available from many sources known in the art. The synthetic thermoset resins and seal members including the same can include various additives and fillers as known in the art in various amounts which do not detract from the desired properties of the seal member. Material for a composite seal member is commercially available from J. J. Orly of Clark, New Jersey.

[0040] Plunger 10 of the present invention comprising seal member 60 is preferably free of an operating mechanical valve, such as known in the prior art, utilized to actuate between an open and a closed position to manage fluids above and below the plunger. Furthermore, the plunger of the present invention is preferably springless and does not utilize a spring or other biasing member in order to maintain composite seal member 60 biased outwardly towards the inner diameter of well tubing. Such mechanical springs can have problems with failure as known in the art.

[0041] In yet a further embodiment of the present invention, at least the metal exterior surfaces of plunger 10 are provided with a surface coating 66 that has a lower coefficient of friction than the layer or layers the surface coating is applied thereto. Surface coating 66 aids in reducing friction. Surface coating 66 is preferably one or more layers of plating upon a metal layer of plunger 10. Preferred coatings comprise chrome, and preferably hard chrome. Surface coating 66 can include chrome such as thvalent chrome or hexavalent chrome. A hard chrome finish has been found to prevent
rust, thereby extending the life of the plunger 10. The surface coating 66 can be applied to any thickness, but generally ranges from about .0001 to about 0.05 inch, and preferably from about 0.0005 to about 0.001 inch. The hardness of the surface coating, preferably chrome, is generally greater than or equal to about 60 to about 72 Rockwell, and is preferably from about 64 to about 67 Rockwell (ASTM E18). A hard chrome finish can reduce friction, when compared to a tool grade steel in an amount generally from about 50 to about 100%.

[0042] Plunger 10, upper segment 18 and lower segment 20 are preferably formed of a suitable metal such as steel or other suitably serviceable material. Tool grade steel is utilized in a preferred embodiment. Thermoplastics or thermoset material can be utilized in various embodiments.

[0043] The plunger 10 of the present invention provides a valveless plunger which is simple and economical to manufacture. The plunger is lightweight, yet durable and wear resistant. The reduced mass of the plunger increases net gas lift. Wear resistance of the composite seal member maintains sealing tolerances over an extended life rating. Lift capability is enhanced, and is maintained over a prolonged life. The ridge and groove structure further enhances lift capability of the plunger.

[0044] FIG. 2 shows one embodiment of an overall schematic of a well pumping system 100 that can utilize plunger 10 of the present invention. Well 110 extends from the ground level 112 down to a sub-surface, such as an oil and/or gas bearing formation 114. The well includes an outer casing 116 having a plurality of apertures 118 formed through its sidewall adjacent formation 114 for admitting oil or gas, or both. The string of tubing 120 extends down within the casing and has an open bottom 122. In one embodiment, a seeding nipple or abutment 124 secured within the tubing and also has an open bottom 126. The top of the tubing extends upward through a master valve 128 to a plunger collar 130 which catches the plunger when it reaches the collar 130. Output flow line 132 is connected to tubing 120. The flow line 132 can contain a motor valve 134 operated by a timer 136 that maintains a valve between opened and closed positions. Plunger 10 is shown resting on nipple 124 at the beginning of a cycle of
operation with motor valve 134 closed. Gas and oil from formation 114 enters casing 116 through apertures 118. A slug of fluid, such as oil or gas, builds up within tubing 20. After a predetermined time lapse, the timer 136 opens motor valve 134 which enables gas in the upper part of tubing to escape through flow line 132. This creates a pressure differential across plunger 10, and the greater pressure beneath the plunger drives the plunger upwardly. The upwardly driven plunger pulls a slug of fluid upwardly and outwardly through open flow line 132 to a collection means (not shown). When the plunger reaches the top, motor valve 134 is closed and the pressure on the top and the bottom of the plunger equalizes. The plunger falls back under the influence of gravity slowly back down through the oil or gas in the tubing and comes to rest against the seeding nipple 124. Motor valve 134 is again opened after a predetermined time, and the cycle is repeated.

[0045] Example

[0046] In order to illustrate the benefits of the plunger of the present invention including a thermoset seal member, the following experiment was performed. The same well was utilized for all tests. The well depth was 3,800 feet and the well tubing had an inner diameter of 1.610 inches. The control plunger was a padded spring-type plunger commercially available from Ferguson Beauregard of Tyler, Texas as Ultra Flex Plunger. Over a period of lifting cycles, the control plunger averaged about 10 inches according to a gas chart. A plunger of the present invention including 11 ridges and 11 grooves, as well as a fiber reinforced phenolic seal member was placed in the well, under similar pressures and conditions. The remaining features of the plunger have been described herein. During an initial number of runs, the plunger of the present invention averaged between about 40 and about 45 on the gas chart. The run times were able to be increased from 2 times per day with the control plunger to 3 times a day and further to 4 times a day with the new plunger. The average amount of time that the control plunger took to ascend from the bottom of the well to the top of the plunger catcher was about 7 minutes and 12 seconds. The plunger of the present invention significantly reduced time for ascension, with initial times averaging about 4 minutes and 16 seconds, and then the average time further decreased to about 3 minutes and
28 seconds. At the average cycle time of 3 minutes and 28 seconds, about 56 to about 64 inches was averaged on the gas chart, which translates into more production in less time with greater efficiency.

[0047] Advantages of the plungers of the present invention include increased production, such as from about 50 to about 100 percent increase. The plungers have been found to significantly reduce run time thus making the well perform more efficiently. Run times can be increased from about 25 to about 100 percent. Plungers of the present invention having a surface coating of hard chrome have reduced friction which allows the plunger to run quicker up the tubing and is believed to extend the life of the well. It is believed that on older, lower pressure wells with quite a bit of fluid, the plungers of the present invention can preclude a producer from having to change a well over to a pump jack thus potentially saving the producer many thousands of dollars. It is believed that the seal member keeps fluid under the plunger and makes the plunger ascend up the hole faster, cleaner and with less weight on top of the plunger, with the fluid being brought up under the plunger instead of on top of the plunger.

[0048] In accordance with the patent statutes, the best mode and preferred embodiment have been set forth; the scope of the invention is not limited thereto, but rather by the scope of the attached claims.
WHAT IS CLAIMED IS:

1. A plunger for a plunger lift pumping system, comprising:
   an elongated cylindrical body comprising an upper segment connected to a lower segment by a fastener wherein the upper segment includes a plurality of circumferential ridges and a plurality of circumferential grooves on an exterior of the body, wherein the lower segment includes an end stop and a seal member carrier located above the end stop and having an outer diameter less than an outer diameter of the end stop; and
   a seal member, wherein the seal member is substantially cylindrical and has an aperture extending through a longitudinal axis of the seal member, wherein the seal member carrier extends through the seal member aperture, wherein an outer diameter of a portion of the end stop and a portion of the upper segment are each greater than an inner diameter of the seal member to maintain the seal member operatively connected to the body, and wherein the seal member comprises a thermoset resin.

2. The plunger according to claim 1, wherein the seal member is a composite seal member comprising fiber reinforced thermoset resin.

3. The plunger according to claim 2, wherein the fiber is woven or non-woven or a combination thereof, natural or synthetic or a combination thereof, and wherein the fiber comprises cotton, wood or wood pulp, abaca, alpaca, bamboo, cashmere, coconut fiber, flax, hemp, jute, kenaf, mohair, silk, sisal, soybean fiber, wool, a polymeric fiber, glass, fiberglass, or a combination thereof.

4. The plunger according to claim 2, wherein the fiber is one or more of canvas, liner, paper and wood pulp.

5. The plunger according to claim 2, wherein the thermoset resin is one or more of a phenolic resin, melamine resin, silicone resin, urea-formaldehyde resin, thermosetting polyester resin and epoxy resin.
6. The plunger according to claim 2, wherein the thermoset resin is a phenolic resin and wherein the fiber is one or more of canvas, linen, paper and wood pulp.

7. The plunger according to claim 1, wherein the plunger is free of a mechanical value and wherein the plunger is springless.

8. The plunger according to claim 6, wherein the upper segment is connected to the lower segment by threading.

9. The plunger according to claim 8, wherein from about 6 to about 14 ridges are present, and wherein from about 6 to about 14 grooves are present, wherein the ridges comprise a substantially flat plateau, wherein each groove has a substantially flat valley, wherein an angled region is present at each end of at least one groove leading to two different ridges, wherein an angle created by an intersection of lines drawn from the angled regions has an angle of from about 20° to about 120°.

10. The plunger according to claim 1, wherein the plunger is adapted to be utilized in about a 1.610 inch inner diameter well tube, wherein the plunger has a fishing neck having a length of about 1 to about 3 inches, and a collar having an outer diameter of from about 1.496 to about 1.507 inches, wherein the plunger upper segment has a section including the collar, plurality of ridges and plurality of grooves and has a length of from about 6 to about 10 inches measured along the longitudinal axis, wherein the end stop has a length from about 1 to about 2 inches, and wherein the seal member has a maximum outer diameter of from about 1.501 to about 1.608 inches.

11. The plunger according to claim 1, wherein the plunger is adapted to be utilized in about a 1.995 inch inner diameter well tube, wherein the plunger has a fishing neck having a length of about 1.5 to about 3.5 inches, a collar having an outer diameter of from about 1.846 to about 1.857 inches, wherein the plunger upper segment has a section including the collar, plurality of ridges and plurality of grooves that has a length
of from about 8 to about 14 inches measured along the longitudinal axis, wherein the end stop has a length from about 1 to about 2 inches, and wherein the seal member has a maximum outer diameter of from about 1.848 to about 1.995 inches.

12. The plunger according to claim 1, wherein the plunger includes a surface coating having a Rockwell hardness greater than or equal to 60.

13. The plunger according to claim 12, wherein the surface coating comprises chrome.

14. A plunger for a plunger lift pumping system, comprising:
   an elongated cylindrical body comprising an upper segment and a lower segment, a tubular seal member disposed on the body above an end stop of the upper segment, wherein an outer diameter of a portion of the end stop and a portion of the upper segment are greater than an inner diameter of the seal member to maintain the seal member operatively connected to the body, wherein a seal member carrier extends through the inner diameter of the seal member, wherein the seal member carrier has a maximum outer diameter which is less than the inner diameter of the seal member and a clearance is provided between the seal member and seal member carrier, wherein the seal member comprises a thermoset resin optionally including fibers, wherein the body has a chrome-containing surface coating having a Rockwell hardness greater than or equal to 60.

15. The plunger according to claim 14, wherein the surface coating has a Rockwell hardness from 60 to about 72.

16. The plunger according to claim 15, wherein the seal member is a composite seal member comprising fiber reinforced thermoset resin.

17. The plunger according to claim 16, wherein the fiber is woven or non-woven or a combination thereof, natural or synthetic or a combination thereof, wherein
the fiber comprises cotton, wood or wood pulp, abaca, alpaca, bamboo, cashmere, coconut fiber, flax, hemp, jute, kenaf, mohair, silk, sisal, soybean fiber, wool, a polymeric fiber, glass, fiberglass, or a combination thereof, and wherein the thermoset resin is one or more of a phenolic resin, melamine resin, silicone resin, urea-formaldehyde resin, thermosetting polyester resin and epoxy resin.

17. The plunger according to claim 16, wherein the thermoset resin is a phenolic resin, wherein the fiber is one or more of canvas, linen, paper and wood pulp, wherein the plunger is free of a mechanical value, wherein the plunger is springless, and wherein the upper segment is connected to the lower segment by threading.

18. A seal member for a plunger for a plunger lift pumping system, comprising:
   an elongated tubular body having a cylindrical inner diameter, wherein the body has a substantially cylindrical outer diameter having chamfered ends, wherein the chamfered ends each have a length that independently range from about 0.25 to about 1 inch measured along a longitudinal axis of the seal member, wherein each chamfered end tapers individually at an angle of from about 1° to about 20° measured parallel to the longitudinal axis of the seal member, and wherein the seal member comprises a thermoset resin.

19. The seal member according to claim 18, wherein the seal member is a composite seal member comprising fiber reinforced thermoset resin, wherein the fiber is woven or non-woven or a combination thereof, natural or synthetic or a combination thereof, and wherein the fiber comprises cotton, wood or wood pulp, abaca, alpaca, bamboo, cashmere, coconut fiber, flax, hemp, jute, kenaf, mohair, silk, sisal, soybean fiber, wool, a polymeric fiber, glass, fiberglass, or a combination thereof.

20. The seal member according to claim 19, wherein the thermoset resin is one or more of a phenolic resin, melamine resin, silicone resin, urea-formaldehyde resin, thermosetting polyester resin and epoxy resin.
FIG. 6
### A. CLASSIFICATION OF SUBJECT MATTER

**IPC(8) -** E21 B 33/12 (2008.04)
**USPC -** 166/101

According to International Patent Classification (IPC) or to both national classification and IPC

### B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

<table>
<thead>
<tr>
<th>IPC(8)</th>
<th>USPC</th>
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<td>E21B 33/12 (2008.04)</td>
<td>166/101</td>
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</table>

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

USPC 166/68, 106, 372, 166/

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PubWEST (USPTO, PGPB, EPAB, IPAB), Google/Patents, Google/Web

Search Terms: oil, gas, gasoline, petroleum, well, plunger, thread, screw, groove, ridge, channel, slot, trench, rib, resin, thermoset polymer, phenolic, polymer, plastic, seal, stopper, plug, barrier, block, cork, fiber, strand, chrome, plating, Rockwell, hardness

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No</th>
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<tbody>
<tr>
<td>Y</td>
<td>US 3,181,470 A (CLINGMAN) 04 May 1965 (04 05 1965), Figs 1-3, col 3, Ins 11-14, 35-40 56-63</td>
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<td>2-6 8, 9, 14-17 19-21</td>
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<td>12 13, 14-17, 21</td>
</tr>
</tbody>
</table>

* Further documents are listed in the continuation of Box C

T: later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

X: document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Y: document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

&: document member of the same patent family

### Date of the actual completion of the international search

27 August 2008 (27 08 2008)

### Date of mailing of the international search report

04 SEP 2008

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