



(22) Date de dépôt/Filing Date: 2000/04/10

(41) Mise à la disp. pub./Open to Public Insp.: 2001/10/10

(51) Cl.Int.⁷/Int.Cl.⁷ E21B 33/04

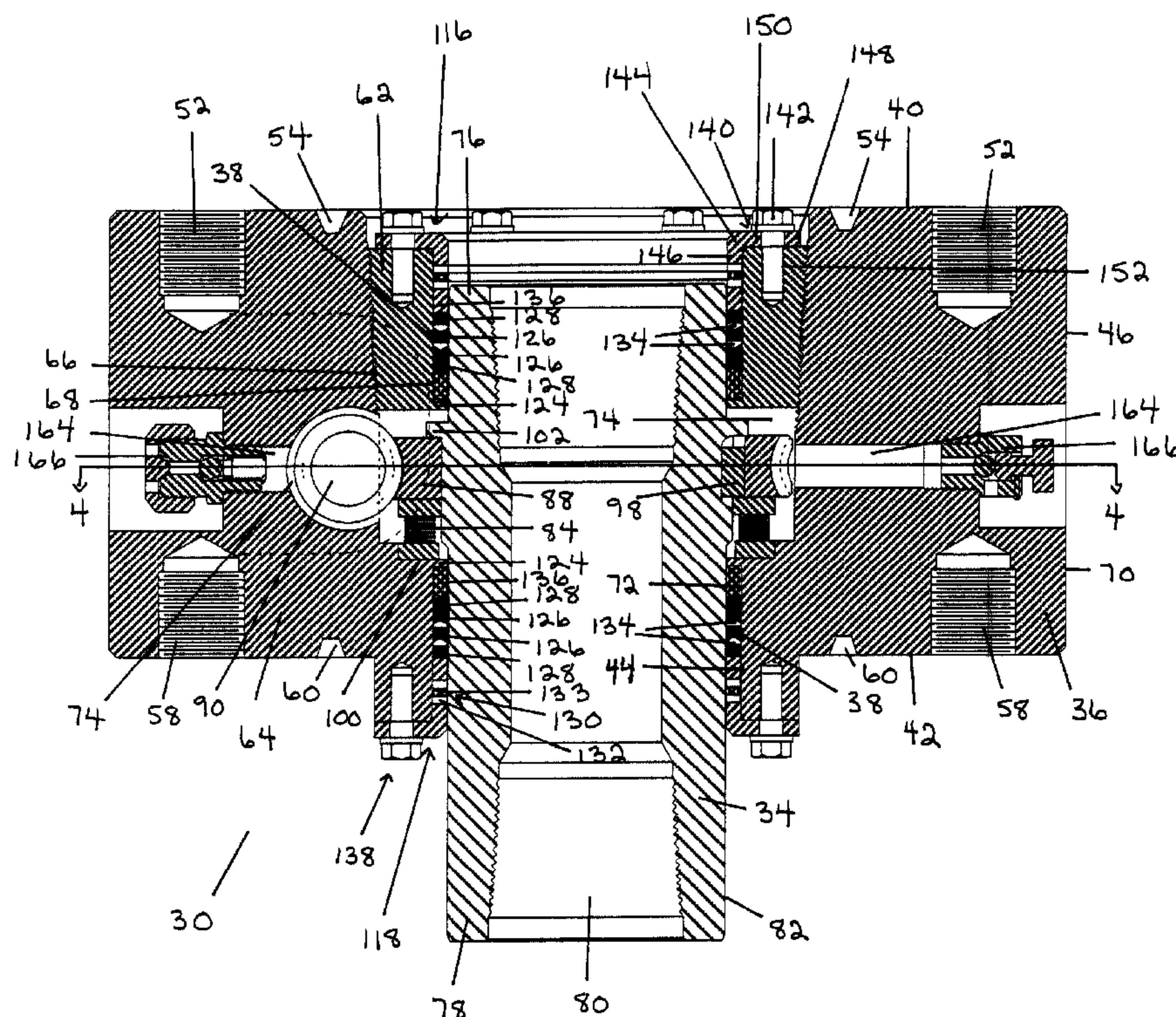
(71) Demandeur/Applicant:
CAMPBELL INDUSTRIES LTD., CA

(72) Inventeur/Inventor:
BLAND, LINDEN H., CA

(74) Agent: FIELD ATKINSON PERRATON

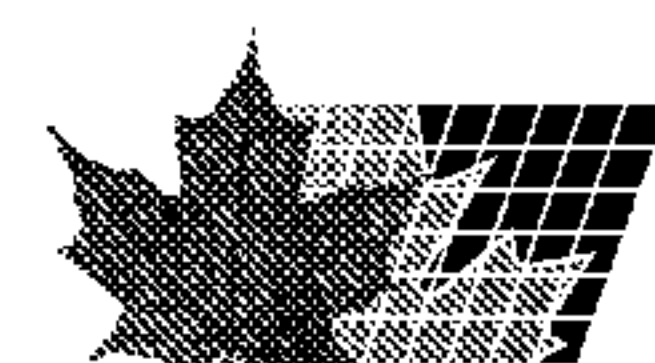
(54) Titre : APPAREIL D'ETANCHEIFICATION POUR ROTATEUR DE TUBES

(54) Title: SEALING ASSEMBLY FOR A TUBING ROTATOR



(57) **Abrégé/Abstract:**

A sealing assembly in combination with an apparatus for attachment to a wellhead for suspending and rotating a tubing string contained within a wellbore and the apparatus comprised of the sealing assembly. The apparatus is comprised of an outer member and an inner mandrel rotatably supported within the outer member for connection with the tubing string and defining an annular space between the outer member and the inner mandrel. The sealing assembly is comprised of a sealing element contained within the annular space for sealing between the outer member and the inner mandrel; a biasing mechanism contained within the annular space for applying an axial force to the sealing element such that the sealing element is compressed to seal the annular space; and an energizing mechanism associated with one of the outer member and the inner mandrel for loading the biasing mechanism.



ABSTRACT OF INVENTION

A sealing assembly in combination with an apparatus for attachment to a wellhead for suspending and rotating a tubing string contained within a wellbore and the apparatus comprised of the sealing assembly. The apparatus is comprised of an outer member and an inner mandrel rotatably supported within the outer member for connection with the tubing string and defining an annular space between the outer member and the inner mandrel. The sealing assembly is comprised of: a sealing element contained within the annular space for sealing between the outer member and the inner mandrel; a biasing mechanism contained within the annular space for applying an axial force to the sealing element such that the sealing element is compressed to seal the annular space; and an energizing mechanism associated with one of the outer member and the inner mandrel for loading the biasing mechanism.

SEALING ASSEMBLY FOR A TUBING ROTATOR

FIELD OF INVENTION

5 The within invention relates to a sealing assembly in combination with an apparatus for attachment to a wellhead for suspending and rotating a tubing string contained within a wellbore, referred to as a tubing rotator. Further, the within invention relates to a tubing rotator comprised of at least one sealing assembly as described herein. More particularly, the invention relates to a tubing rotator having particular application for use with wells experiencing
10 relatively high temperatures and pressures.

BACKGROUND OF INVENTION

15 A typical oilfield wellhead includes a casing head, casing bowl or tubing head which engages or is otherwise mounted to a casing string contained within a wellbore of a well at the surface. The casing head, casing bowl or tubing head is typically directly or indirectly connected or engaged with an upper end of a tubing string which is contained within the wellbore. Thus, the tubing string is suspended within the wellbore. A reciprocating rod or tube or a rotating rod or tube is then run through the tubing string for production of the well.

20 Often a typical oilfield wellhead will further include a tubing rotator to suspend and rotate the tubing string within the wellbore. By rotating the tubing string, typical wear occurring within the internal surface of the tubing string by the reciprocating or rotating rod string is distributed over the entire internal surface. As a result, the tubing rotator may prolong
25 the life of the tubing string.

 Typically, a sealing assembly or seals are required within the tubing rotator to prevent leakage of production fluids from the rotating tubing hanger back down the wellbore annulus, to a drive gear system or drive mechanism of the tubing rotator or to the outside
30 environment.

Typically, oil wells produce at a temperature of less than or equal to about 300°F. Therefore, the seal materials within the tubing rotator may be comprised of standard elastomeric O-rings or polyseals capable of operating at temperatures of up to 400°F. In addition, some more exotic elastomers such as Kalrez™ may be used at temperatures of up to 550°F.

5

However, temperatures greater than about 300°F often occur in oil wells that employ steam injection to heat the oil *in-situ*. Such wells usually produce from zones containing heavy (viscous) oil that will not flow into the wellbore without the addition of heat. Increasing the temperature of heavy (viscous) oil drastically reduces its viscosity so that it will flow to the wellbore. Where steam injection or other thermal methods of causing temperature increase within the formation are employed, the temperature of the produced fluids from the wellbore may reach temperatures as high as about 650°F. Further, steam injection is typically done at saturation pressure, being 2208.8 psia for steam at 650°F.

10

Saturation pressure and temperature is the state at which water and water vapor (steam) co-exist. Typically, steam injection is done with a mixture (quality) of 80%; that is, 80% by weight of the mixture is water vapor and 20% is liquid. This mixture has been found to be optimal in that the 20% water will carry all minerals that are contained within the softened source water and prevent the minerals from scaling or plating out on the steam boiler heating surfaces. Accordingly, the tubing rotator used in these applications is preferably capable of withstanding such relatively high temperatures of up to about 650°F., as well as withstanding such relatively high pressures of up to about 2208.8 psia while at this temperature.

15

20

Conventional elastomeric seals for sealing between rotating parts or members tend to break down under these conditions due to the combined effects of the high temperature, the high pressure and the rotation. As a result, other packing or sealing materials, such as graphite, may be used that will withstand such temperatures and pressures. However, these materials are non-elastomeric, which means that they have no "memory" and thus will not rebound or return to their original shape when the compressive sealing forces are removed from them. As a result, even if these materials are initially compressed sufficiently to cause a seal, as soon as they wear or the compressing force is relaxed, they will begin to leak. In other words, non-elastomeric

25

30

seals, such as graphite seals, are therefore "all or nothing" seals in that they are either pressurized or energized or non-pressurized or non-energized.

5 Consequently, as seals comprised of non-elastomeric material become worn, the compressive sealing forces applied to them must continuously be increased to compensate for any loss in thickness of the seal. In other words, the seals are initially energized to provide the seal and then re-energized as wear occurs to maintain the seal. As a result, these packing materials tend to be employed where the compressing or re-energizing force can be manually or mechanically re-applied when wear occurs. For instance, these types of packing materials are
10 often employed in oil well stuffing boxes or on valve stem packings of high temperature valves where the packing force can be re-introduced manually when required. In some cases, springs such as Belleville springs, being dish-shaped washers, are used to maintain the compressive force on the packing.

15 Further, packing materials, such as graphite packing, which are a relatively solid non-elastomeric material often require a relatively high compressive force to cause them to flow and seal between the two surfaces where the seal is desired. As a result, the use of non-elastomeric materials may make it relatively difficult to move or rotate one surface relative to another due to the friction drag of the highly compressed packing material.

20 In high temperature, high pressure applications for tubing rotators, leakage to the drive system or drive mechanism compartment of the tubing rotator or externally to the environment cannot be tolerated and must be minimized if not prevented altogether. Specifically, any leakage at these high temperatures and pressures will increase rapidly if not
25 immediately stopped. In addition, the seals typically located within the tubing rotator are not readily accessible for tightening or re-energizing manually. Finally, seals located within the tubing rotator must be dynamic seals such that adjacent surfaces must be permitted to rotate relative to one another.

30 There is therefore a need in the industry for a tubing rotator including or combined with a sealing assembly capable of withstanding relatively high temperatures and high pressures,

such as those typically found in steam injection wells experiencing temperatures of up to about 650°F. and pressures of up to about 2208.8 psia. Further, there is a need for the sealing assembly to be energized, pressurized or compressed by a mechanism, device or method that is self actuating as needed such that it does not require external intervention. Finally, there is a need for a sealing assembly that does not require an excessive energizing or compressive force that will result in a heavy drag between the sealing surfaces such that the operation of the tubing rotator is impeded or otherwise interfered with.

In addition, the overall configuration or design of the tubing rotator including the sealing assembly preferably maintains the overall strength and integrity of the wellhead, adds a minimum of height to the wellhead, facilitates or permits existing well servicing procedures to be carried out and is relatively safe and reliable as compared to known tubing rotators.

SUMMARY OF INVENTION

The within invention relates to a sealing assembly in combination with an apparatus for attachment to a wellhead for suspending and rotating a tubing string contained within a wellbore, referred to as a tubing rotator. Further, the within invention relates to a tubing rotator comprised of at least one sealing assembly as described herein. As well, the invention relates to a dynamic sealing assembly for use in applications where a relatively high temperature, a relatively high pressure and rotating parts or members are encountered. For instance, the tubing rotator comprised of the sealing assembly of the within invention has been found to be particularly useful for suspending and rotating the tubing string within a wellbore experiencing temperatures as high as about 650°F. and pressures as high as about 2208.8 psia.

Further, the within invention relates to a sealing assembly which provides some "memory" for non-elastomeric type seals. Specifically, the sealing assembly combines a non-elastomeric seal material or sealing element with a self-actuating biasing mechanism so that a compressive sealing force may be continuously applied when the non-elastomeric seal material experiences the effects of wear without the need for external intervention. In other words, once

the sealing material or sealing element is energized, the biasing mechanism preferably compensates for wear of the sealing material by automatically re-energizing the seal material.

In addition, the sealing assembly of the within invention is preferably unaffected by the elements within its environment. In particular, the biasing mechanism is preferably positioned within the tubing rotator such that it is not readily clogged or contaminated with debris which may interfere with its proper functioning. As well, the biasing mechanism preferably acts upon other elements or components of the sealing assembly which similarly are not readily clogged or contaminated with debris.

In a first aspect of the invention, the invention is comprised of a sealing assembly in combination with an apparatus for attachment to a wellhead for suspending and rotating a tubing string contained within a wellbore. The apparatus is comprised of an outer member and an inner mandrel rotatably supported within the outer member for connection with the tubing string and defining an annular space between the outer member and the inner mandrel. The sealing assembly is comprised of:

- (a) a sealing element contained within the annular space for sealing between the outer member and the inner mandrel;
- (b) a biasing mechanism contained within the annular space for applying an axial force to the sealing element such that the sealing element is compressed to seal the annular space; and
- (c) an energizing mechanism associated with one of the outer member and the inner mandrel for loading the biasing mechanism.

In a second aspect of the invention, the invention is comprised of an apparatus for attachment to a wellhead for suspending and rotating a tubing string contained within a wellbore, the apparatus comprising:

- (a) an inner mandrel for connection with the tubing string;
- (b) an outer member for rotatably supporting the inner mandrel therein, wherein an annular space is defined between the outer member and the inner mandrel;
- (c) a drive mechanism operatively engaging the inner mandrel for rotating the inner mandrel within the outer member; and
- (d) at least one sealing assembly for sealing the annular space between the outer member and the inner mandrel, wherein the sealing assembly is comprised of:
- (i) a sealing element contained within the annular space for sealing between the outer member and the inner mandrel;
- (ii) a biasing mechanism contained within the annular space for applying an axial force to the sealing element such that the sealing element is compressed to seal the annular space; and
- (iii) an energizing mechanism associated with one of the outer member and the inner mandrel for loading the biasing mechanism.

In both the first and second aspects of the invention, the apparatus may be any type or configuration of tubing rotator comprised of an outer member, outer housing or outer mandrel connectable with or mountable upon the wellhead and further comprised of an inner mandrel, inner member or inner tubing connectable with the tubing string and rotatably supported within the outer member such that an annular space is defined therebetween. The sealing assembly of the within invention is provided for sealing between the outer member and the inner mandrel.

Preferably, the outer member has an upper end and a lower end. The apparatus may include a single sealing assembly of the within invention such that the sealing assembly seals the annular space between the outer member and the inner mandrel at any location or

position therein between the upper end and the lower end of the outer member. However, preferably, the annular space is sealed adjacent the upper end of the outer member and is further sealed adjacent the lower end of the outer member. As a result, fluids are inhibited from passing into or out of the outer member, between the outer member and the inner mandrel, at both the
5 upper and lower ends of the outer mandrel. Accordingly, a sealed chamber is preferably provided between the upper and lower ends of the outer member. In this case, the particular sealing assembly of the within invention would seal the annular space adjacent either the upper end or the lower end of the outer member. Sealing adjacent the other end of the outer member would be provided or performed by any other type or configuration of seal, sealing structure or
10 sealing mechanism.

However, preferably, the apparatus or tubing rotator is comprised of an upper sealing assembly for sealing the annular space adjacent the upper end of the outer member and a lower sealing assembly for sealing the annular space adjacent the lower end of the outer member.
15 In other words, both sealing assemblies adjacent the upper and lower ends of the outer member are preferably configured in accordance with the sealing assembly of the within invention. As a result, fluids are inhibited from passing into or out of the outer member, between the outer member and the inner mandrel, at both the upper and lower ends of the outer mandrel to provide a sealed chamber in the outer member between the upper and lower sealing assemblies. Further,
20 in the preferred embodiment, each of the upper sealing assembly and the lower sealing assembly are substantially similar. Thus, any discussion or description herein relating to the sealing assembly generally is equally applicable to both the upper sealing assembly and the lower sealing assembly.

25 Further, the outer member preferably defines a drive chamber communicating with the annular space between the upper sealing assembly and the lower sealing assembly. Thus, the drive chamber preferably comprises the sealed chamber between the upper and lower sealing assemblies. The drive chamber is provided for containing all or any part or portion of the drive mechanism of the apparatus or the tubing rotator therein. In the event that any part or portion of
30 the drive mechanism exits or passes out of the outer member, the outer member is preferably further sealed at this location such that the sealing of the drive chamber is maintained. This

further seal may be provided by a sealing assembly of the within invention or it may be provided by any other type or configuration of seal, sealing structure or sealing mechanism.

Any type or configuration of drive mechanism may be used which is capable of
5 operatively engaging the inner mandrel in order to rotate the inner mandrel within the outer member. The drive mechanism may operatively engage the inner mandrel at any location or position along the length of the inner mandrel. However, preferably, the drive mechanism operatively engages the inner mandrel within the drive chamber. Thus, preferably, any type or configuration of drive mechanism may be used which is capable of operatively engaging the
10 inner mandrel within the drive chamber.

Further, the drive mechanism is preferably comprised of a driven gear associated with the inner mandrel and a drive gear for engaging the driven gear. Thus, preferably, the drive gear operatively engages the driven gear within the drive chamber. Any type or configuration of
15 drive gear and driven gear system may be used. However, preferably, the gear system is comprised of a worm and worm gear. More particularly, in the preferred embodiment, the driven gear is comprised of a worm gear associated with the inner mandrel, while the drive gear is comprised of a worm. Thus, rotation of the worm acts upon the worm gear in order to rotate the inner mandrel within the outer member.

20

In addition, in the preferred embodiment, the worm is associated with a worm shaft such that rotation of the worm shaft rotates the worm. Further, the worm is contained within the drive chamber, while the worm shaft extends from the drive chamber and exits out of the outer member through the outer member. As a result, in the preferred embodiment, as
25 discussed above, the worm shaft is sealed with the outer member as it passes through the outer member in order to maintain the sealed drive chamber. This seal may be provided by a further sealing assembly of the within invention or by any other type or configuration of seal, sealing structure or sealing mechanism.

30

As well, in the first and second aspects of the invention, the sealing element of each sealing assembly may be comprised of any type of material capable of sealing the annular

space. For instance, the sealing element may be elastomeric or non-elastomeric. In the preferred embodiment, the sealing element is comprised of a non-elastomeric seal. More particularly, the non-elastomeric seal is preferably comprised of graphite. In the preferred embodiment, the non-elastomeric seal is comprised of at least one graphite ring.

5

Thus, the sealing element of each sealing assembly, being a non-elastomeric seal, may be comprised of a single graphite ring contained within the annular space for sealing between the inner mandrel and the outer member. However, preferably, the sealing element is layered in that the sealing element is comprised of at least two, and preferably at least three, 10 graphite rings layered or stacked together within the annular space to comprise the sealing element. In the preferred embodiment, the sealing element or non-elastomeric seal is comprised of at least three graphite rings wherein at least one central graphite ring is positioned between two outer graphite rings.

15

Each of the graphite rings may be comprised of any type or configuration of graphite or graphite packing suitable for sealing the annular space. Further, each central graphite ring and each of the two outer graphite rings may be comprised of the same type or configuration of graphite or graphite packing or may be comprised of different types or configurations of graphite or graphite packing. However, preferably, each central graphite ring is comprised of the 20 same type or configuration of graphite or graphite packing. Further, each of the outer graphite rings is preferably comprised of the same type or configuration of graphite or graphite packing. In the preferred embodiment, the outer graphite rings are comprised of graphite packing rope. In addition, in the preferred embodiment, the central graphite ring or at least one central graphite ring is comprised of a graphoil seal.

25

With respect to each sealing assembly, the application of the axial force to the sealing element by the biasing mechanism may compress the sealing element to seal the annular space in any manner and by any structure or mechanism capable of compressing the sealing element. However, preferably, the sealing assembly is further comprised of a shoulder associated 30 with one of the inner mandrel and the outer member and extending within the annular space. In this instance, the sealing element is contained within the annular space between the shoulder and

the biasing mechanism such that the sealing element is compressed between the shoulder and the biasing mechanism upon application of the axial force. In the preferred embodiment, the shoulder is associated with the outer member such that the shoulder extends from the outer member within the annular space. The shoulder may be integrally formed with the outer member
5 or it may be mounted, fastened, connected or otherwise attached with the outer member.

Further, in order to facilitate or enhance the sealing of the annular space by the non-elastomeric seal, while still permitting the rotation of the inner mandrel within the outer member, the sealing assembly is further preferably comprised of a chevron bushing contiguous
10 with the non-elastomeric seal for deflecting the non-elastomeric seal laterally within the annular space upon the application of the axial force by the biasing mechanism. More preferably, the chevron bushing is contiguous with one or more of the graphite rings such that the graphite ring is deflected laterally. In the preferred embodiment, the chevron bushing is contiguous with the central graphite ring for deflecting the central graphite ring laterally within the annular space
15 upon the application of the axial force by the biasing mechanism. Where the non-elastomeric seal is comprised of greater than one central graphite ring, a chevron bushing is preferably contiguous with each central graphite ring.

The biasing mechanism may be comprised of any mechanism, structure or device
20 able to be contained within the annular space and capable of applying the axial force to the sealing element. However, the biasing mechanism is preferably comprised of at least one spring for applying the axial force to the sealing element. Thus, in the preferred embodiment, the biasing mechanism is comprised of at least one spring for applying the axial force to one or more graphite rings which comprise the non-elastomeric seal such that the graphite ring is compressed
25 and deflected laterally to seal the annular space. Although any type or configuration of spring or springs may be used, the biasing mechanism is preferably comprised of at least one Belleville spring.

The energizing mechanism of each sealing assembly may be associated with either
30 the outer member or the inner mandrel and may be comprised of any mechanism, structure or device capable of loading the biasing mechanism in order to energize the sealing element.

Preferably, the energizing mechanism is comprised of an adjustable retainer associated with one of the outer member and the inner mandrel and movable within the annular space such that the retainer is adjustable towards the biasing mechanism for loading the biasing mechanism. In the preferred embodiment, the adjustable retainer is associated with the outer member.

5

More particularly, the adjustable retainer is preferably comprised of a tightening mechanism associated with the outer member and a retainer plate having an inner end movable within the annular space and an outer end associated with the tightening mechanism such that tightening of the tightening mechanism adjusts the position of the retainer plate within the annular space towards the biasing mechanism. In the preferred embodiment, the tightening mechanism is comprised of a bolt or screw which extends through the outer end of the retainer plate for engagement with the outer member. More particularly, the bolt or screw is preferably threaded for threaded engagement with the outer member such that turning or screwing of the bolt into or out of the outer member moves the inner end of the retainer plate within the annular space. In the preferred embodiment, tightening of the screw into the outer member adjusts the position of the retainer plate towards the biasing mechanism.

10

15

20

Finally, the sealing assembly is further preferably comprised of at least one bushing contained within the annular space for laterally supporting the inner mandrel. More preferably, at least one bushing is preferably positioned or located adjacent each end of the sealing element, or adjacent each of the outer graphite rings, such that the sealing element is positioned therebetween. Any type of bushing may be used, such as a bronze or steel bushing.

BRIEF DESCRIPTION OF DRAWINGS

25

Embodiments of the invention will now be described with reference to the accompanying drawings, in which:

30

Figure 1 is a side view of a wellhead wherein a preferred embodiment of an apparatus for suspending and rotating a tubing string within a wellbore is attached thereto;

Figure 2 is a longitudinal sectional view of the apparatus shown in Figure 1 including a preferred embodiment of a sealing assembly;

Figure 3 is a more detailed view of the sealing assembly shown in Figure 2; and

Figure 4 is a cross-sectional view of the apparatus taken along line 4 – 4 of Figure 2.

DETAILED DESCRIPTION

Referring to Figure 1, a typical wellhead (20) is comprised of a plurality of components mounted at the ground surface above the wellbore. A rod or rod string (22) is run through the wellhead (20) and into the wellbore through a continuous fluid passage or pathway which extends through each of the components of the wellhead (20). As shown in Figure 1, the well may be produced by a reciprocating rod or tube (22) reciprocated by a pump jack or walking beam (24) at the surface. Alternately, the well may be produced by a rotating rod or tube (22) driven by a rotary pump drive (not shown) at the surface.

Further, a typical wellhead (20) is comprised of a casing head (26), casing bowl, tubing head or tubing bowl which engages or is otherwise mounted to a casing string (28) contained within the wellbore of the well at the surface. An apparatus (30) for suspending and rotating a tubing string (32) contained within the wellbore, referred to herein as a tubing rotator, may be mounted upon an upper surface of the casing head (26). As indicated, the tubing rotator (30) is connected to or engages an upper end of the tubing string (32) which is contained within the wellbore.

Referring to Figures 2 – 4, the apparatus or tubing rotator (30) is comprised of an inner mandrel (34) for connection with the tubing string (32) and an outer member (35) for rotatably supporting the inner mandrel (34) therein such that an annular space (38) is defined or provided between the inner mandrel (34) and the outer member (36).

More particularly, referring to Figures 2 and 4, the outer member (36) has an upper end (40), a lower end (42), an internal bore (44) extending between the upper and lower ends (40, 42) and an outer wall (46). The outer member (36) may be of any shape or configuration suitable for its intended function purpose as described herein. However, the outer member (36) is preferably tubular on cross section, as shown in Figure 4, such that the circumference of the outer member (36) defines the outer wall (46).

The upper end (40) of the outer member (36) is preferably connectable to other components of the wellhead (20) or other wellhead equipment by any fastening or connecting means, mechanism, structure or device suitable for temporarily fastening or connecting the outer member (36) to such other wellhead equipment. Although the connection is preferably a temporary connection, permitting the removal of the other equipment, where required or desired the connecting or fastening means may permit or cause a permanent connection between the outer member (36) and the other equipment.

In the preferred embodiment, the upper end (40) of the outer member (36) is connected with other wellhead equipment by a connecting flange (48), as shown in Figure 1, associated with the other wellhead equipment. However, the connecting flange (48) may alternatively be integrally formed, connected, mounted, attached or otherwise associated with the upper end (40) of the outer member (36). In addition, in the preferred embodiment, the upper connecting flange (48) defines at least two apertures, and preferably a plurality of apertures, spaced circumferentially about the upper connecting flange (48). The apertures are provided for receiving fasteners (50), such as bolts, screws, studs or the like, therein such that the other wellhead equipment may be fastened to the outer member (36). Further, the upper end (40) of the outer member (36) preferably defines at least two, and preferably a plurality of, internally threaded cavities (52) spaced circumferentially about the bore (44) of the outer member (36) for receiving the fasteners (50) therein. Finally, an annular groove (54) may be defined by the upper end (40) of the outer member (36) about the circumference of the internal bore (40) for receiving a flange ring or other seal for sealing between the adjacent surfaces of the outer member (36) and the other wellhead equipment.

Similarly, the lower end (42) of the outer member (36) is preferably connectable to the casing head (26) or any other suitable components of the wellhead (20) or wellhead equipment by any means, structure, device or mechanism suitable for mounting the outer member (36) to the particular wellhead structure may be used as long as it is compatible with the function and purpose of the outer member (36) and the tubing rotator (30). Further, the connection may provide for either a temporary or a permanent connection between the outer member (36) and the wellhead structure to which it is attached. In the preferred embodiment, the lower end (42) of the outer member (36) is removably or detachably mounted or connected with the casing head (26).

In the preferred embodiment, the lower end (42) of the outer member (36) is connected with the casing head (26) by a connecting flange (56), as shown in Figure 1, associated with the casing head (26). However, the connecting flange (56) may alternatively be integrally formed, connected, mounted, attached or otherwise associated with the lower end (42) of the outer member (36). In addition, in the preferred embodiment, the lower connecting flange (56) also defines at least two apertures, and preferably a plurality of apertures, spaced circumferentially about the connecting flange (56). The apertures are provided for receiving fasteners (50), such as bolts, screws, studs or the like, therein such that the casing head (26) may be fastened to the outer member (36). Further, the lower end (42) of the outer member (36) preferably defines at least two, and preferably a plurality of, internally threaded cavities (58) spaced circumferentially about the bore (44) of the outer member (36) for receiving the fasteners (50) therein. Finally, an annular groove (60) may be defined by the lower end (42) of the outer member (36) about the circumference of the internal bore (40) for receiving a flange ring or other seal for sealing between the adjacent surfaces of the outer member (36) and the casing head (26).

Further, the outer member (36) may be comprised of one integral piece or element or it may be comprised of two or more pieces, parts or elements connected, temporarily or permanently together to form the outer member (36). In the preferred embodiment, the outer member (36) is comprised of two pieces, parts or members removably connected together in order to facilitate the manufacture and maintenance of the tubing rotator (30) and the placement and removal of the inner mandrel (34) within the bore (44) of the outer member (36).

Specifically, the outer member (36) is comprised of a tubular outer mandrel (62) removably connected with or mounted within a surrounding housing (64).

Specifically, the outer mandrel (62) has an outer surface (66) and an inner surface (68). Further, the housing (64) has an outer surface (70) and an inner surface (72). The outer mandrel (62) is preferably removably mounted within the housing (64) adjacent either the upper end (40) or the lower end (42) of the outer member (36). Alternatively, an outer mandrel (62) may be mounted within the housing adjacent both the upper and lower ends (40, 42) of the outer member (36). In the preferred embodiment, a single outer mandrel (62) is removably mounted within the housing (64) adjacent the upper end (40) of the outer member (36).

In particular, the outer mandrel (62) is mounted within the inner surface (72) of the housing (64) adjacent the upper end (40) such that the outer surface (66) of the outer mandrel (62) sealingly engages the adjacent inner surface (72) of the housing (64). In particular, a threaded engagement is preferably provided therebetween to provide a metal to metal seal. In other words, a threaded inner surface (72) of the housing (64) engages a threaded outer surface (66) of the outer mandrel (62). Further, the outer mandrel (62) is configured and mounted within the housing (64) such that the inner surface (68) of the outer mandrel (62) defines the bore (44) of the outer member (36) adjacent its upper end (40), while the inner surface (72) of the housing (64) defines the bore (44) of the outer member (36) adjacent its lower end (42).

With respect to the threads between the outer surface (66) of the outer mandrel (62) and the adjacent inner surface (72) of the housing (64), these threads are preferably tapered so that the screwing of the outer mandrel (62) into the housing (64) creates the metal to metal seal between the threads of the outer mandrel (62) and the housing (64). A torque of 700 to 1000 foot-pounds applied to the outer mandrel (62) has been found to provide a positive seal. In addition, a thermal seal thread compound, such as that provided by Topco Company, may also be used to facilitate a positive seal.

Further, the outer member (36), and in particular the housing (64), defines a drive chamber (74) therein which communicates with the annular space (38) provided between the bore (44) of the outer member (36) and the inner mandrel (34) rotatably suspended therein.

5 The inner mandrel (34) may be comprised of any tubular member, element or structure permitting the passage of the rod string (22) and wellbore fluids therethrough. Further, the inner mandrel (34) includes an upper end (76), a lower end (38), a bore (80) extending therethrough and an outer surface (82). The upper end (76) of the inner mandrel (34) is preferably positioned adjacent the upper end (40) of the outer member (36), while the lower end
10 (78) of the inner mandrel (34) preferably extends from the lower end (42) of the outer member (36) for connection with the tubing string (32). However, the lower end (78) of the inner mandrel (34) need not extend from the lower end (42) of the outer member (36). The annular space (38) is defined between the bore (44) of the outer member (36) and the outer surface (82) of the inner mandrel (34).

15 Further, the upper end (76) of the inner mandrel (34) is preferably connectable with other tools or tubing within the wellhead (20) such that the rod string (22) and wellbore fluids may pass therebetween or in order to remove the inner mandrel (34) or the tubing rotator (30) from the wellhead (20). Thus, the bore (80) of the inner mandrel (34) adjacent the upper
20 end (76) is preferably threaded. Similarly, the lower end (78) of the inner mandrel (34) is connectable with the tubing string (32) within the wellbore such that the rod string (22) and the wellbore fluids may pass between the tubing string (32) and the inner mandrel (34). Thus, the bore (80) of the inner mandrel (34) adjacent the lower end (78) is also preferably threaded.

25 As indicated, the inner mandrel (34) is rotatably supported by the outer member such that the longitudinal movement of the of the inner mandrel (34) relative to the outer member (36) in a direction towards the lower end (42) of the outer member (36) is inhibited. Any means, mechanism, device or structure capable of supporting the inner mandrel (34) in the required manner which is compatible with the function of the tubing rotator (30), may be used. However,
30 preferably, the inner mandrel (34) is rotatably supported within the outer member (36) by at least one bearing (84) located between the inner mandrel (34) and the outer member (36) such that the

bearing (84) is seated on the outer member (36) and the inner mandrel (34) is rotatably supported upon the bearing (84). Any bearing (84) suitable for, and compatible with, this intended purpose or function may be used. For instance, the bearing (84) may be comprised of a thrust bearing, a radial bearing, a tapered roller bearing, a roller thrust bearing or a combination thereof.

5

In addition, the tubing rotator (30) is comprised of a drive mechanism (86) operatively engaging the inner mandrel (34) for rotating the inner mandrel (34) within the outer member (36). More particularly, the drive mechanism (86) preferably operatively engages the inner mandrel (34) within the drive chamber (74). Although any type or configuration of drive
10 mechanism (86) may be used, the drive mechanism (86) is preferably comprised of a driven gear (88) associated with the inner mandrel (34) and a drive gear (90) for engaging the driven gear (88). As indicated, the drive gear (90) preferably engages the driven gear (88) within the drive chamber (74).

15

Further, the inner mandrel (34) is associated with the driven gear (88) such that rotation of the driven gear (88) causes the inner mandrel (34) to rotate within the outer member (36). Any structure, device, mechanism or means for associating the inner mandrel (34) and the driven gear (88) in the described manner may be used. However, in the preferred embodiment, the driven gear (88) is fixedly mounted or connected about the outer surface (82) of the inner
20 mandrel (34) such that the driven gear (88) extends from the inner mandrel (34) towards the drive chamber (74) for engagement with the drive gear (90). Thus, the driven gear (88) is preferably located along the inner mandrel (34) at a position such that the driven gear (88) is adjacent to the drive gear (90) when the inner mandrel (34) is located within the internal bore (44) of the outer member (36).

25

The driven gear (88) may be mounted or otherwise fastened to the inner mandrel (34) by any suitable means, structure, device or mechanism for mounting or fastening the driven gear (88) thereto. However, in the preferred embodiment, as shown in Figures 2 and 4, an inside surface (92) of the driven gear (88) defines a keyway (94) which is compatible with a keyway
30 (96) defined by the adjacent outer surface (82) of the inner mandrel (34). Alignment of the keyways (94, 96) and the insertion of a key or dowel (98) therein provides at least in part for the

mounting of the driven gear (88) with the inner mandrel (34) and inhibits the rotation of the driven gear (88) relative to the inner mandrel (34).

5 In addition, the particular manner in which the inner mandrel (34) is rotatably supported by the outer member (36) further provides for the mounting of the driven gear (88) with the inner mandrel (34). In the preferred embodiment, the bore (44) of the outer member (36), and particularly, the inner surface (72) of the housing (64) includes an upwardly facing support shoulder (100). A lower end of the bearing (84) is seated upon the shoulder (100). The driven gear (88) is then seated upon an upper end of the bearing (84) such that the driven gear
10 (88), and therefore the inner mandrel (34), is rotatably supported upon the outer member (36). Finally, the outer surface (82) of the inner mandrel (34) defines a downwardly facing shoulder which is seated upon the driven gear (88).

15 In this manner, the downward longitudinal movement of the inner mandrel (34) relative to the outer member (36) is inhibited. Further, downward longitudinal movement of the inner mandrel (34) relative to the outer member (36) is also inhibited by the engagement of the shoulder (102) with the outer member (36), and particularly with the outer mandrel (62). However, any means, mechanism, structure or device capable of performing this function may be used.

20

As stated, the drive mechanism (86) of the apparatus (30) is comprised of the drive gear (90) and the driven gear (88). The drive gear (90) is preferably of a type and configuration which is able to be accommodated or contained within the drive chamber (74) and which is compatible with the driven gear (88) such that the drive gear (90) may releasably engage the
25 driven gear (88) when the inner mandrel (34) is located within the bore (44) of the outer member (36). The driven gear (88) is also of a type and configuration which is able to be accommodated or contained within the drive chamber (74) and which is compatible with the drive gear (90) such that the driven gear (88) may releasably engage the drive gear (90).

30

The drive gear (90) and the driven gear (88) may be comprised of any gears capable of performing the functions or purposes set out above, and which permit the drive gear

(90) and the driven gear (88) to engage each other within the drive chamber (74). However, preferably, the drive gear (90) is comprised of a worm and the driven gear (88) is comprised of a worm gear. Any suitable worm (90) and worm gear (88) may be used.

5 Referring to Figure 4, in the preferred embodiment, the worm (90) is comprised of a worm shaft (104) having a first end (106) and a second end (108). The worm (90), and in particular the worm shaft (104), is rotatably supported within the drive chamber (74) such that the worm shaft (104) may rotate about its longitudinal axis and such that the worm (90) is positioned to engage the worm gear (88) so that rotation of the worm shaft (104) causes rotation
10 of the worm gear (88).

The worm (90), and more particularly the worm shaft (104) may be rotatably supported within the drive chamber (74) by any means, mechanism, structure or device suitable for, and capable of, supporting the worm shaft (104) in the desired manner such that the worm
15 (90) may perform its function or purpose as described herein. In the preferred embodiment, the first end (106) of the worm shaft (104) is positioned within the drive chamber (74) and rotatably supported by a bushing (110), preferably a bronze bushing. The second end (108) of the worm shaft (104) extends through and beyond the outer wall (46) of the outer member (36).

20 Thus, the outer wall (46) of the outer member (36) defines an opening for passage of the second end (108) of the worm shaft (104) therethrough such that the second end (108) of the worm shaft (104) is outside of the outer member (36). Preferably, the outer member (36) is sealed with the worm shaft (104) as it passes out of the outer member (36), as discussed further below. Further, one or more bearings (112) and one or more bushings (114) are preferably
25 mounted about the worm shaft (104) to rotatably support the worm shaft (136) within the outer member (36). Any bearing (112) suitable for, and compatible with, this intended purpose or function may be used. For instance, the bearing (152) may be comprised of a thrust bearing, a radial bearing, a tapered roller bearing or a combination thereof.

30 The apparatus (30) is further comprised of at least one sealing assembly for sealing the annular space (38) between the bore (44) of the outer member (36) and the outer surface (82)

of the inner mandrel (34). However, preferably, the annular space (38) is sealed adjacent the upper end (40) of the outer member (36) and adjacent the lower end (42) of the outer member (36). As a result, fluids are inhibited from passing into or out of the drive chamber (74) defined by the outer member (36). In other words, the drive chamber (74) is preferably sealed at the upper and lower ends (40, 42) of the outer member (36).

Thus, in the preferred embodiment, the apparatus or tubing rotator (30) is comprised of an upper sealing assembly (116) for sealing the annular space (38) adjacent the upper end (40) of the outer member (36) and a lower sealing assembly (118) for sealing the annular space (38) adjacent the lower end (42) of the outer member (36). More particularly, the upper and lower sealing assemblies (116, 118) provide a seal between the outer surface (82) of the inner mandrel (34) and the bore (44) of the outer member (36). Thus, in the preferred embodiment, the upper sealing assembly (116) provides a seal between the outer surface (82) of the inner mandrel (34) and the inner surface (68) of the outer mandrel (62), while the lower sealing assembly (118) provides a seal between the outer surface (82) of the inner mandrel (34) and the inner surface (72) of the housing (64).

Both the upper and lower sealing assemblies (116, 118) are preferably configured in accordance with the preferred embodiment of the sealing assembly as described herein. Therefore, the description contained herein relating generally to the sealing assembly is equally applicable to both the upper and lower sealing assemblies (116, 118).

As indicated, the sealed drive chamber (74) communicating with the annular space (38) is preferably provided between the upper sealing assembly (116) and the lower sealing assembly (118). As a result, in the preferred embodiment, in order to maintain a sealed drive chamber (74), a further seal or sealing structure (120) is provided where the worm shaft (104) exits the outer member (36). This further sealing structure (120) may similarly be comprised of a sealing assembly of the within invention substantially similar to the upper and lower sealing assemblies (116, 118). However, given that the sealing structure (120) of the worm shaft (104) is externally accessible, any other type or configuration of seal, sealing structure or sealing mechanism may be used.

Referring to Figures 2 and 3, each sealing assembly (116, 118) of the apparatus (30) is comprised of a sealing element (122) contained within the annular space (38) for sealing between the outer member (36) and the inner mandrel (34) as described above. In the preferred embodiment, the sealing element (122) of each sealing assembly (116, 118) is maintained in a desired position within the annular space (38), at least in part, by a shoulder (124) extending within the annular space (38). Specifically, each sealing assembly (116, 118) is preferably comprised of a shoulder (124) associated with one of the inner mandrel (34) and the outer member (36) which extends within the annular space (38).

In the preferred embodiment, the shoulder (124) is preferably positioned or located at an innermost end of each sealing assembly (116, 118) within the outer member (36) in order to inhibit the passage or movement of the sealing assembly (116, 118) into the drive chamber (74). Further, in the preferred embodiment, the shoulder (124) of each sealing assembly (116, 118) is associated with the outer member (36) such that the shoulder (124) extends from the outer member (36) within the annular space (38). Preferably, the shoulder (124) is integrally formed with the outer member (36). Thus, in the preferred embodiment, the shoulder (124) of the upper sealing assembly (116) is integrally formed with the inner surface (68) of the outer mandrel (62), while the shoulder (124) of the lower sealing assembly (118) is integrally formed with the inner surface (72) of the housing (64).

The sealing element (122) of each sealing assembly (116, 118) may be comprised of any type of material capable of sealing the annular space (38). However, preferably, the sealing element (122) is comprised of a non-elastomeric seal. In addition, the non-elastomeric seal is preferably comprised of graphite. In the preferred embodiment, the non-elastomeric seal is comprised of at least three graphite rings wherein at least one central graphite ring (126) is positioned between two outer graphite rings (128). More preferably, two central graphite rings (26) are positioned between the outer graphite rings (128).

In the preferred embodiment, the outer graphite rings (128) are each comprised of graphite packing rope. In addition, in the preferred embodiment, the central graphite rings (126) are each comprised of a graphoil seal.

5 It has been found that graphite is a preferable seal material as it has been found to withstand temperatures of up to 1200°F. It also tends to be relatively chemically resistant to steam, crude oil, salt water, H₂S, CO₂ and other corrosive fluids. Graphite alone, however, will extrude. As a result, a carbon yarn material or metallic mesh may be interwoven with the graphite to form a graphite ring or packing which resists extrusion. This form of graphite ring or
10 packing is available commercially in the form of a long square rope and is referred to herein as graphite packing rope. The graphite packing rope is typically cut to lengths equal to the circumference of the annular space (38) and is stacked into the annular space (38) with the splice of each succeeding graphite packing rope situated 180° from that of the next. The cut of each graphite packing rope is usually made at a 45 degree angle. In the preferred embodiment,
15 graphite packing rope has a cross-section ¼ inch x ¼ inch. As stated, the outer graphite rings (128) are each preferably comprised of graphite packing rope. An example of graphite packing rope is supplied by A.R. Thompson Group and is referred to as "HS-3000 RGS Graphite Packing."

20 The central graphite rings (126) are each preferably comprised of a type of graphite ring or packing referred to herein as a graphoil seal. A graphoil seal is a die cast graphite ring, typically ¼ inch x ¼ inch in cross-section. An example of a graphoil seal is a "GOFR Graphoil Seal" supplied by A.R. Thompson Group. To manufacture the graphoil seal, the graphite is formed into a long ribbon which is wrapped around an inner mandrel of a die.
25 The inner mandrel of the die is then placed inside an outer mandrel of the die. The space between the two mandrels forms a space identical to that of the rotator annular space (38). A cylindrical sleeve is then pressed into the space between the mandrels of the die mould to form the graphite ring or seal. The graphoil seals comprising the central graphite rings (126) are inhibited or prevented from extruding by the presence of the graphite packing rope which
30 comprises the outer graphite rings (128) surrounding, or at either end of, the central graphite rings (126).

Each sealing assembly (116, 118) is further comprised of a biasing mechanism (130) substantially contained within the annular space (38) for applying an axial force to the sealing element (122), preferably the graphite rings (126, 128), such that the sealing element (122) is compressed to seal the annular space (38). More particularly, in the preferred embodiment, the sealing element (122) is contained within the annular space (38) between the shoulder (124) and the biasing mechanism (130) such that the sealing element (122) is compressed between the shoulder (124) and the biasing mechanism (130) upon application of the axial force.

The biasing mechanism (130) is preferably comprised of at least one spring (132), and preferably two springs (132) in a stacked or layered arrangement, for applying the axial force to the graphite rings (126, 128). In addition, each spring (132) is preferably separated from the adjacent spring (132) by one or more washers (133). In the preferred embodiment, each spring (132) is preferably a Belleville spring. As well, each Belleville spring (132) is preferably manufactured from InconelTM so that it will not be tempered by the high temperature and lose its spring force.

In addition, in the preferred embodiment, in order to facilitate or enhance the sealing of the annular space (38), each sealing assembly (116, 118) is further preferably comprised of at least one chevron bushing (134) contiguous with the non-elastomeric seal (122) for deflecting the non-elastomeric seal (122) laterally within the annular space (38) upon the application of the axial force by the biasing mechanism (130). More preferably, the chevron bushing (134) is contiguous with one or more of the graphite rings (126, 128). In particular, the central graphite rings (126) are each comprised of a graphoil seal which is more likely to extrude upon the application of the axial force. As a result, in the preferred embodiment, a chevron bushing (134) is contiguous with each central graphite ring (126) for deflecting the central graphite ring (126) laterally within the annular space (38) upon the application of the axial force by the biasing mechanism (130).

Further, the chevron bushings (134) are preferably positioned in the sealing assemblies (116, 118) as described in order that the pressure required to create a seal in the annular space (38) is not so high as to cause an unacceptable drag on the rotating inner mandrel (34). The chevron bushings (134) deflect the graphite material of the inner graphite rings (126) laterally against the sealing surfaces so that a seal is obtained without applying extreme pressure. Typically, the required pressure applied at the Belleville springs (132) is about 3000 pounds, and the springs (132) are designed to exert this pressure when fully compressed. When this pressure is applied, typically the torque required to rotate the inner mandrel (34) is about 40 foot-pounds.

Each sealing assembly (116, 118) is further preferably comprised of at least one bushing (136) contained within the annular space (38) for laterally supporting the inner mandrel (34). It has been found that lateral force on the inner mandrel (34) results from the driving force of the worm (90) on the worm gear (88) and can also result on wells that are slant drilled. More preferably, at least one bushing (136) is preferably positioned or located adjacent each end of the sealing element (122), or adjacent each of the outer graphite rings (128), such that the sealing element (122) is positioned therebetween. Any type of bushing (136) may be used, such as a bronze or steel bushing. However, the bushing (136) located or positioned between the shoulder (124) and the outer graphite ring (128) is preferably bronze, while the bushing (136) located or positioned between the springs (132) and the other outer graphite ring (128) is preferably steel.

Each sealing assembly (116, 118) is further comprised of an energizing mechanism (138) associated with one of the outer member (36) and the inner mandrel (34) for loading the biasing mechanism (130). Preferably, each energizing mechanism (138) is associated with the outer member (36) such that the energizing mechanism (138) remains relatively stationary as the inner mandrel (34) rotates within the outer member (36). Further, once the biasing mechanism (130) is loaded or energized by the energizing mechanism (138), the entire sealing assembly (116, 118) tends to remain relatively stationary as the inner mandrel (34) rotates relative to the outer member (36). As well, as each energizing mechanism (138) is associated with the outer member (36), in the preferred embodiment, the energizing mechanism (138) of the upper sealing assembly (116) is particularly associated with the outer mandrel (62). The

energizing mechanism (138) of the lower sealing assembly (118) is particularly associated with the housing (64).

5 Preferably, the energizing mechanism (138) of each sealing assembly (116, 118) is comprised of an adjustable retainer (140) associated with the outer member (36) and movable within the annular space (38) such that the retainer (140) is adjustable towards the biasing mechanism (130) for loading or energizing the biasing mechanism (130). More particularly, the adjustable retainer (140) is preferably comprised of a tightening mechanism (142) associated with the outer member (36) and a retainer plate (144). The retainer plate (144) is tubular and has
10 an inner end (146) and an outer end (148). The inner end (146) of the retainer plate (144) extends into and is movable within the annular space (38).

The outer end (148) extends from the annular space (38) and is adjustably or movably mounted, connected or affixed with the adjacent end of the outer member (36) by the
15 tightening mechanism (142). Specifically, the outer end (148) of the retainer plate (144) of the upper sealing assembly (116) is adjustably or movably mounted, connected or affixed with the upper end (40) of the outer member (36) or outer mandrel (62), while the outer end (148) of the retainer plate (144) of the lower sealing assembly (118) is adjustably or movably mounted, connected or affixed with the lower end (42) of the outer member (36) or housing (64).

20

In the preferred embodiment, the outer end (148) of the retainer plate (144) is comprised of a flange (150) which is associated with the tightening mechanism (142) such that tightening of the tightening mechanism (142) adjusts the position of the retainer plate (144) within the annular space (38) towards the biasing mechanism (130). Further, in the preferred
25 embodiment, the tightening mechanism (142) is comprised of a bolt or screw, preferably a hex head screw. The flange (150) of the retainer plate (144) defines one or more apertures therein for the passage of the screw (142) therethrough. Specifically, the screw (142) extends through the aperture in the flange (150) for engagement with the outer member (36). Accordingly, both the upper end (40) and the lower end (42) of the outer member (36) define one or more holes (152)
30 therein, compatible with the apertures in the flange (150), for receiving the screw (142).

More particularly, the screw (142) is preferably externally threaded and each hole (152) is preferably internally threaded such that the screw (142) is threadably engaged with the hole (152). As a result, turning or screwing of the screw (142) into or out of the holes (152) in the outer member (36) adjusts the position of the retainer plate (144) and causes the inner end (146) of the retainer plate (144) to move or be adjusted within the annular space (38). In the preferred embodiment, tightening of the screw (142) into the hole (152) in the outer member (36) adjusts the position of the retainer plate (144) towards the biasing mechanism (130). Thus, the retainer plate (144) may be tightened down onto the Belleville springs (132). Preferably, the total height of the sealing assembly (116, 118) including the springs (132) is selected or configured such that when the retainer plate (144) is tightened down completely, the sealing element (122) is compressed or pressed sufficiently to form a positive seal and the Belleville springs (132) are fully compressed or collapsed. Thus, as the sealing element (122) wears, the Belleville springs (132) will extend to maintain sufficient pressure on the sealing element (122) to maintain the seal.

As indicated, a similar sealing assembly may be provided between the outer member (36) and the worm shaft (104). However, the seal (120) about the worm shaft (104) need not be similar given that the seal (120) is externally accessible and thus, the sealing element may be manually re-energized as it wears. Accordingly, the worm shaft seal (120) may be comprised of any seal, sealing mechanism or sealing structure. However, referring to Figure 4, in the preferred embodiment, the worm shaft seal (120) is comprised of a bushing (114), preferably bronze and preferably having a chevron-shaped end. The chevron shaped end of the bushing (114) is preferably contiguous with an inner graphite ring (156) comprised of a graphoil seal and substantially similar to that described above for the central graphite rings (126) of the sealing assemblies (116, 118). Further, the inner graphite ring (156) is preferably contiguous with an outer graphite ring (158) comprised of graphite packing rope and substantially similar to that described above for the outer graphite rings (128) of the sealing assemblies (116, 118).

A junk ring or washer (16) is preferably positioned adjacent the outermost end of the outer graphite ring (158). All of these components or elements of the worm shaft seal (120) are held in position and compressed or energized between a roller bearing (112), as described

above, and a packing screw (162), preferably a hex head packing screw, externally accessible. Specifically, the packing screw (162) is preferably threadably engaged with the housing (64) such that the packing screw (162) may be screwed or tightened into the housing (64) to energize and re-energize the seal (120) as desired. This seal system (12) is viewed as a secondary seal system, since leakage must first occur past the upper and lower sealing assemblies (116, 118) before it can reach the worm shaft (104).

Finally, the drive chamber (74) is preferably filled with a suitable lubricant such as a high temperature lubricant. In order to access the drive chamber (74) to introduce the lubricant as necessary, the outer member (36) preferably defines one or more vents (164) or conduits therein extending from the drive chamber (74) to the outer wall (46) of the outer member (36). In the preferred embodiment, the outer member (36) defines two vents (164). As shown in Figure 4, one vent (164) extends into the drive chamber (74) adjacent or in proximity to the worm gear (88) opposite the worm (90), while the other vent (164) extends into the drive chamber (74) adjacent or in proximity to the worm shaft (104). Each vent (164) is comprised of a vent fitting or cap (166). Any type or configuration of vent fitting or cap (166) may be used for maintaining a desired pressure of the lubricant within the drive chamber (74).

The embodiments of the invention in which an exclusive privilege or property is claimed are defined as follows:

1. A sealing assembly in combination with an apparatus for attachment to a wellhead
5 for suspending and rotating a tubing string contained within a wellbore, the apparatus comprising an outer member and an inner mandrel rotatably supported within the outer member for connection with the tubing string and defining an annular space between the outer member and the inner mandrel, wherein the sealing assembly is comprised of:
 - 10 (a) a sealing element contained within the annular space for sealing between the outer member and the inner mandrel;
 - (b) a biasing mechanism contained within the annular space for applying an axial
15 force to the sealing element such that the sealing element is compressed to seal the annular space; and
 - (c) an energizing mechanism associated with one of the outer member and the inner mandrel for loading the biasing mechanism.
- 20 2. The sealing assembly as claimed in claim 1 wherein the sealing element is comprised of a non-elastomeric seal.
3. The sealing assembly as claimed in claim 2 further comprising a shoulder
25 associated with one of the inner mandrel and the outer member and extending within the annular space and wherein the sealing element is contained within the annular space between the shoulder and the biasing mechanism such that the sealing element is compressed between the shoulder and the biasing mechanism upon application of the axial force.
4. The sealing assembly as claimed in claim 3 wherein the sealing assembly is further
30 comprised of a chevron bushing contiguous with the non-elastomeric seal for deflecting the non-

elastomeric seal laterally within the annular space upon the application of the axial force by the biasing mechanism.

- 5 5. The sealing assembly as claimed in claim 3 wherein the non-elastomeric seal is comprised of graphite.
6. The sealing assembly as claimed in claim 5 wherein the non-elastomeric seal is comprised of at least one graphite ring.
- 10 7. The sealing assembly as claimed in claim 6 wherein the non-elastomeric seal is comprised of at least three graphite rings wherein at least one central graphite ring is positioned between two outer graphite rings.
- 15 8. The sealing assembly as claimed in claim 7 wherein the outer graphite rings are comprised of graphite packing rope.
9. The sealing assembly as claimed in claim 7 wherein the central graphite ring is comprised of a graphoil seal.
- 20 10. The sealing assembly as claimed in claim 7 wherein the sealing assembly is further comprised of a chevron bushing contiguous with the central graphite ring for deflecting the central graphite ring laterally within the annular space upon the application of the axial force by the biasing mechanism.
- 25 11. The sealing assembly as claimed in claim 10 wherein the biasing mechanism is comprised of at least one spring for applying the axial force to the graphite ring such that the graphite ring is compressed and deflected laterally to seal the annular space.
- 30 12. The sealing assembly as claimed in claim 11 wherein the biasing mechanism is comprised of at least one Belleville spring.

13. The sealing assembly as claimed in 11 wherein the energizing mechanism is comprised of an adjustable retainer associated with one of the outer member and the inner mandrel and movable within the annular space such that the retainer is adjustable towards the biasing mechanism for loading the biasing mechanism.

5

14. The sealing assembly as claimed in claim 13 wherein the adjustable retainer is comprised of a tightening mechanism associated with the outer member and a retainer plate having an inner end movable within the annular space and an outer end associated with the tightening mechanism such that tightening of the tightening mechanism adjusts the position of the retainer plate within the annular space towards the biasing mechanism.

10

15. The sealing assembly as claimed in claim 11 further comprising at least one bushing contained within the annular space for laterally supporting the inner mandrel.

15 16. An apparatus for attachment to a wellhead for suspending and rotating a tubing string contained within a wellbore, the apparatus comprising:

(a) an inner mandrel for connection with the tubing string;

20 (b) an outer member for rotatably supporting the inner mandrel therein, wherein an annular space is defined between the outer member and the inner mandrel;

(c) a drive mechanism operatively engaging the inner mandrel for rotating the inner mandrel within the outer member; and

25

(d) at least one sealing assembly for sealing the annular space between the outer member and the inner mandrel, wherein the sealing assembly is comprised of:

(i) a sealing element contained within the annular space for sealing between the outer member and the inner mandrel;

30

(ii) a biasing mechanism contained within the annular space for applying an axial force to the sealing element such that the sealing element is compressed to seal the annular space; and

5 (iii) an energizing mechanism associated with one of the outer member and the inner mandrel for loading the biasing mechanism.

17. The apparatus as claimed in claim 16 wherein the outer member has an upper end and a lower end and wherein the apparatus is comprised of an upper sealing assembly for sealing
10 the annular space adjacent the upper end of the outer member and a lower sealing assembly for sealing the annular space adjacent the lower end of the outer member.

18. The apparatus as claimed in claim 17 wherein the outer member defines a drive chamber communicating with the annular space between the upper sealing assembly and the
15 lower sealing assembly.

19. The apparatus as claimed in claim 18 wherein the drive mechanism operatively engages the inner mandrel within the drive chamber.

20. The apparatus as claimed in claim 19 wherein the drive mechanism is comprised of a driven gear associated with the inner mandrel and a drive gear for engaging the driven gear, wherein the drive gear operatively engages the driven gear within the drive chamber.

21. The sealing assembly as claimed in claim 17 wherein the sealing element is
25 comprised of a non-elastomeric seal.

22. The sealing assembly as claimed in claim 21 further comprising a shoulder associated with one of the inner mandrel and the outer member and extending within the annular space and wherein the sealing element is contained within the annular space between the
30 shoulder and the biasing mechanism such that the sealing element is compressed between the shoulder and the biasing mechanism upon application of the axial force.

23. The sealing assembly as claimed in claim 22 wherein the sealing assembly is further comprised of a chevron bushing contiguous with the non-elastomeric seal for deflecting the non-elastomeric seal laterally within the annular space upon the application of the axial force
5 by the biasing mechanism.
24. The sealing assembly as claimed in claim 22 wherein the non-elastomeric seal is comprised of graphite.
- 10 25. The sealing assembly as claimed in claim 24 wherein the non-elastomeric seal is comprised of at least one graphite ring.
26. The sealing assembly as claimed in claim 25 wherein the non-elastomeric seal is comprised of at least three graphite rings wherein at least one central graphite ring is positioned
15 between two outer graphite rings.
27. The sealing assembly as claimed in claim 26 wherein the outer graphite rings are comprised of graphite packing rope.
- 20 28. The sealing assembly as claimed in claim 26 wherein the central graphite ring is comprised of a graphoil seal.
29. The sealing assembly as claimed in claim 26 wherein the sealing assembly is further comprised of a chevron bushing contiguous with the central graphite ring for deflecting
25 the central graphite ring laterally within the annular space upon the application of the axial force by the biasing mechanism.
30. The sealing assembly as claimed in claim 29 wherein the biasing mechanism is comprised of at least one spring for applying the axial force to the graphite ring such that the
30 graphite ring is compressed and deflected laterally to seal the annular space.

31. The sealing assembly as claimed in claim 30 wherein the biasing mechanism is comprised of at least one Belleville spring.

32. The sealing assembly as claimed in 30 wherein the energizing mechanism is
5 comprised of an adjustable retainer associated with one of the outer member and the inner mandrel and movable within the annular space such that the retainer is adjustable towards the biasing mechanism for loading the biasing mechanism.

33. The sealing assembly as claimed in claim 32 wherein the adjustable retainer is
10 comprised of a tightening mechanism associated with the outer member and a retainer plate having an inner end movable within the annular space and an outer end associated with the tightening mechanism such that tightening of the tightening mechanism adjusts the position of the retainer plate within the annular space towards the biasing mechanism.

15 34. The sealing assembly as claimed in claim 30 further comprising at least one bushing contained within the annular space for laterally supporting the inner mandrel.

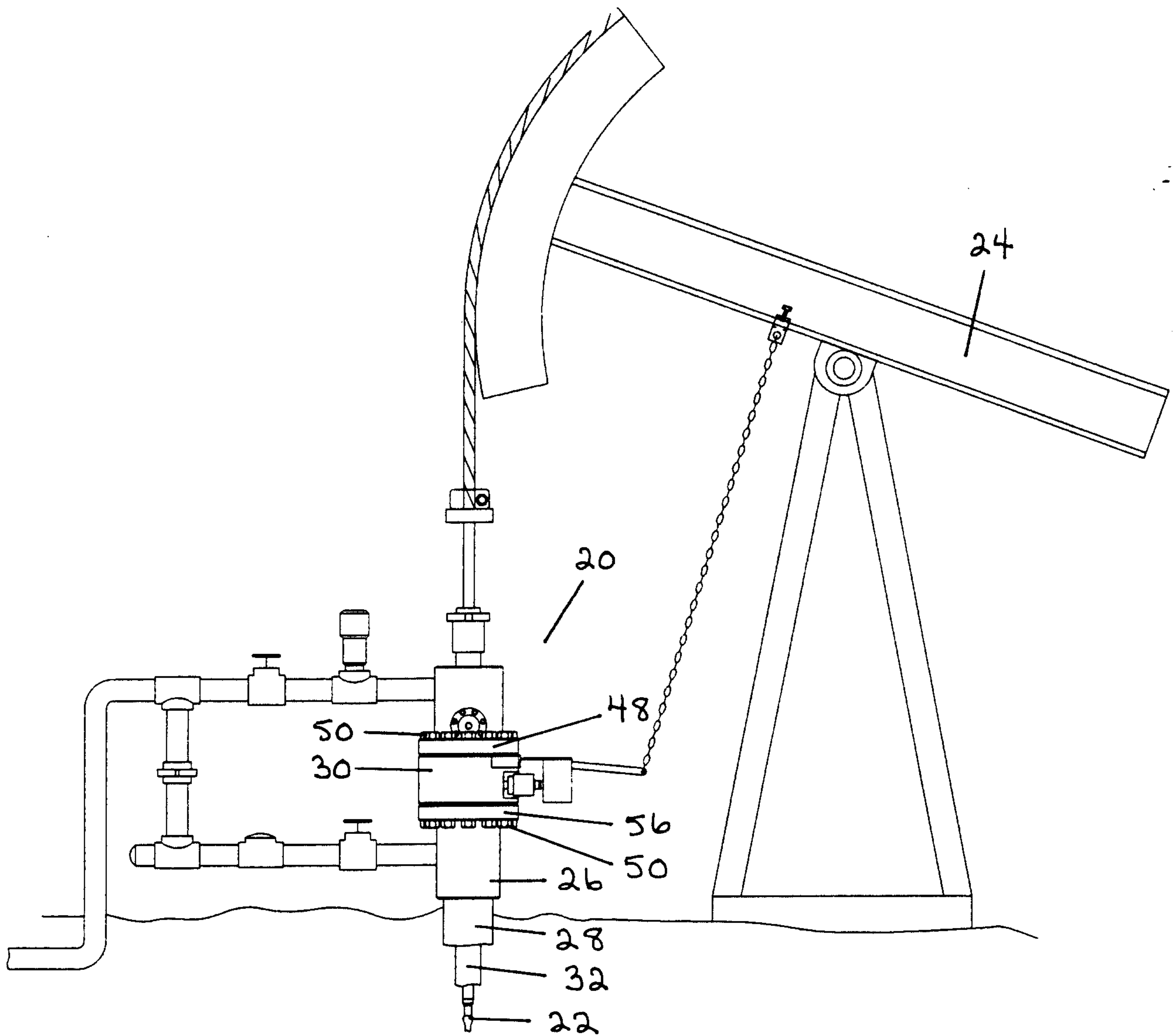


FIGURE 1

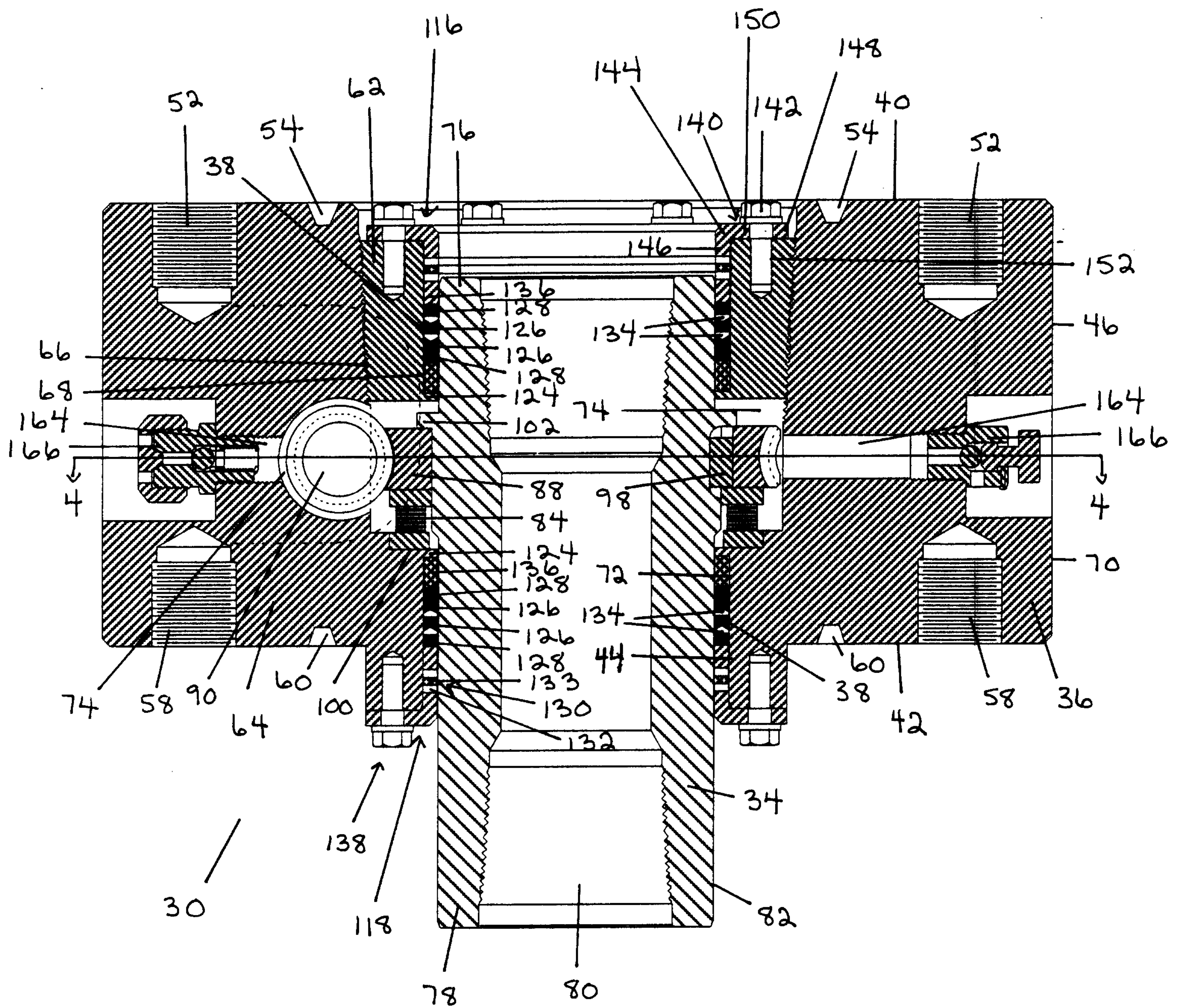


FIGURE 2

