US 20190119993A1

(19) United States
(12) Patent Application Publication
Haynes et al.
(10) Pub. No.: US 2019/0119993 A1
(43) Pub. Date: Apr. 25, 2019

(54) APPARATUS FOR AXIALLY DISPLACING AND TENSIONING A STRING OF PRODUCTION TUBING IN A WELL BORE

(71) Applicant: **Progressive Completions Ltd.**, Leduc County (CA)

(72) Inventors: **Michael Jonathon Haynes**, Leduc County (CA); **Kevin Kelm**, Leduc County (CA)

(73) Assignee: **Progressive Completions Ltd.**

(21) Appl. No.: **15/788,885**

(22) Filed: **Oct. 20, 2017**

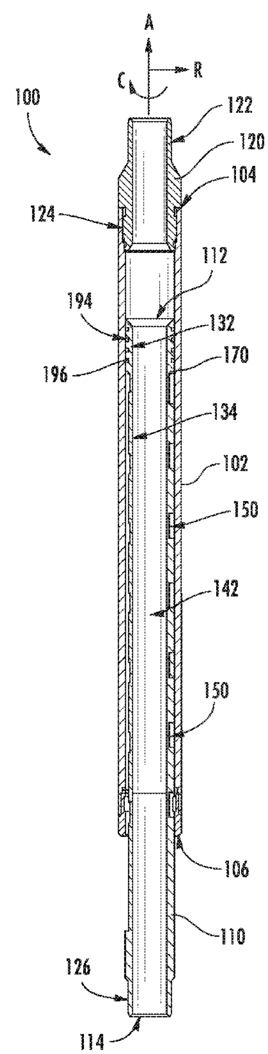
Publication Classification

(51) **Int. Cl.**
E21B 17/07 (2006.01)
E21B 17/042 (2006.01)

(52) **U.S. Cl.**
CPC *E21B 17/07* (2013.01); *E21B 17/042* (2013.01)

(57) **ABSTRACT**

A tensioning tool assembly for supporting a string of oil production piping extending through a well bore includes an outer barrel and a telescoping inner mandrel slidably positioned within the outer barrel. The inner mandrel defines a plurality of axially-spaced slots configured to receive protruding members extending from the outer barrel to fix the relative axial position of the inner mandrel and outer barrel. In this manner, a string of production tubing may be axially displaced by moving inner mandrel to the desired axial position or tension and then rotating inner mandrel to lock the tensioning tool assembly and the attached production tubing. The inner mandrel may further define threaded features for attaching a pull rod and/or a central passageway for supplying fluid to control well pressures.



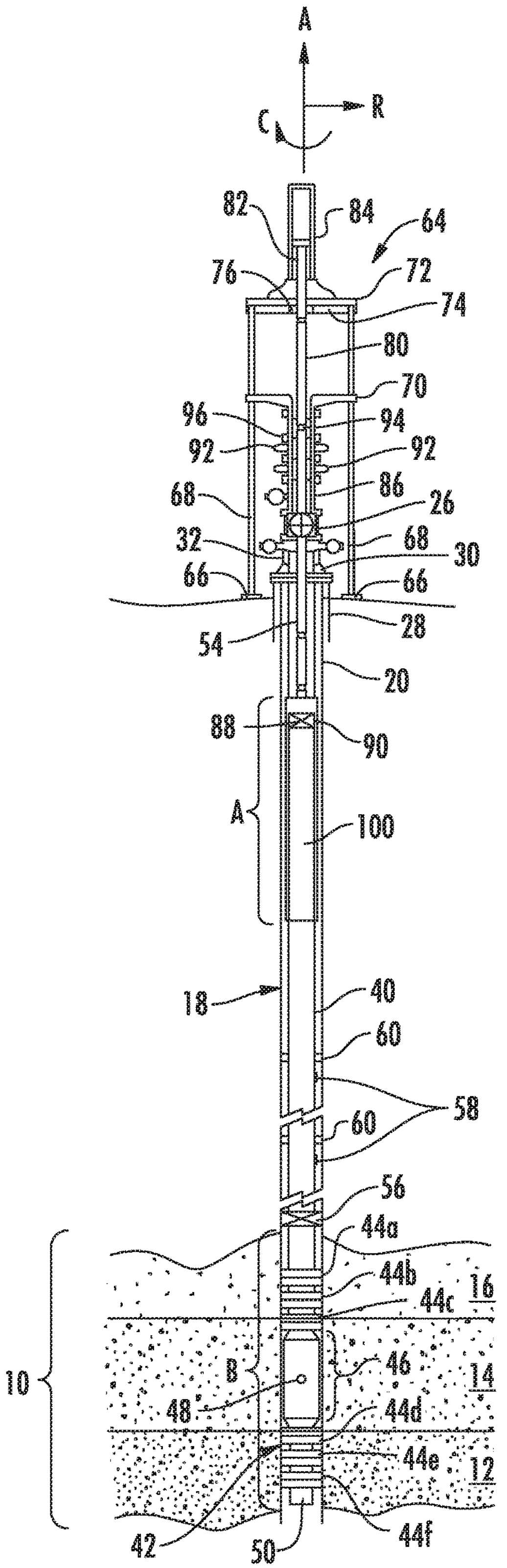
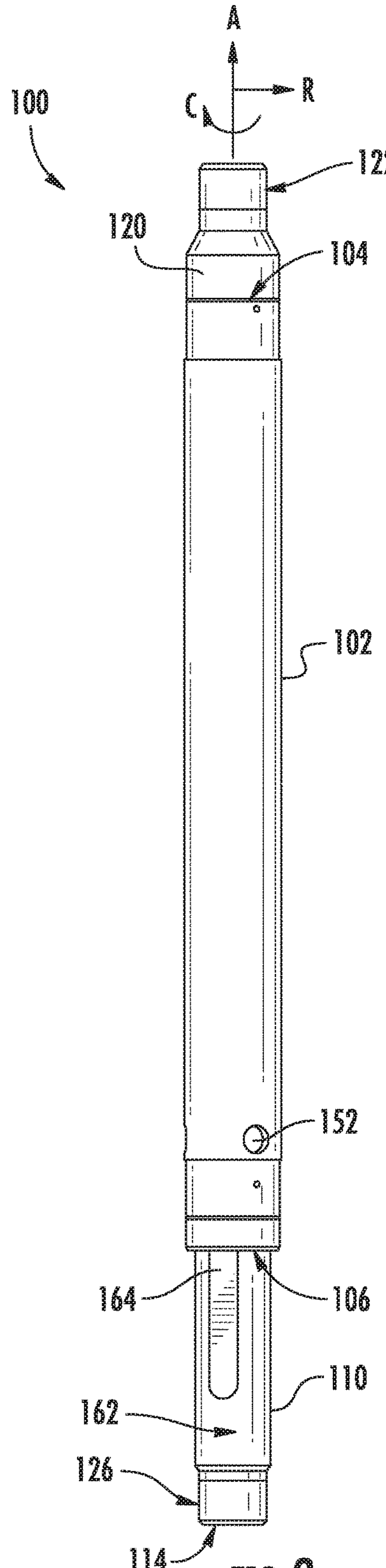
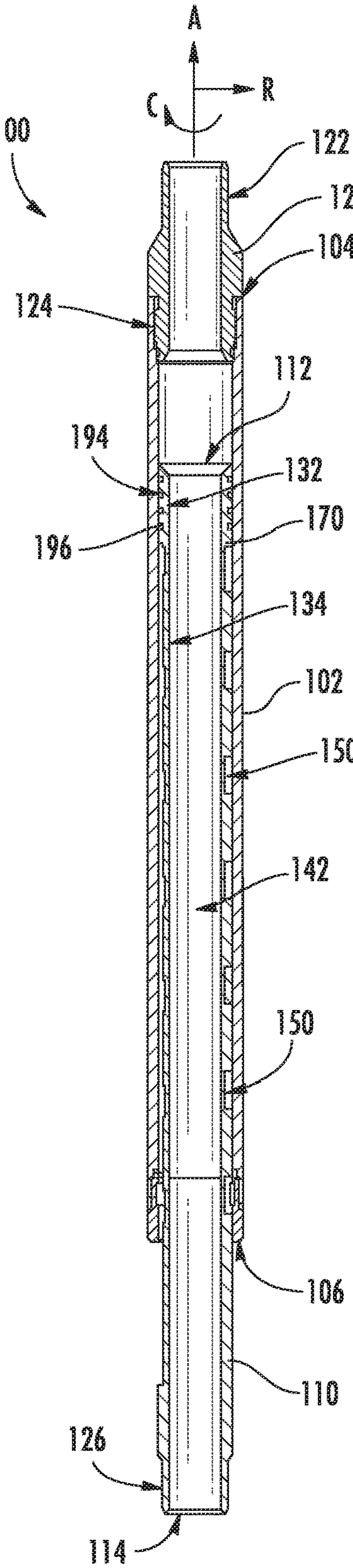

A
R
C
82
84
64
76
72
74
80
70
96
94
92
92
86
68
26
32
68
30
66
66
54
28
20
88
90
A
100
18
40
60
58
60
56
44a
44b
16
44c
10
B
46
14
48
44d
44e
12
42
50
44f

FIG. 1



A
C
R
100
122
120
104
102
152
164
106
110
162
126
114

FIG. 2



A
C
R
100
122
120
104
124
112
194
132
196
170
134
102
150
142
150
106
110
126
114

FIG. 3

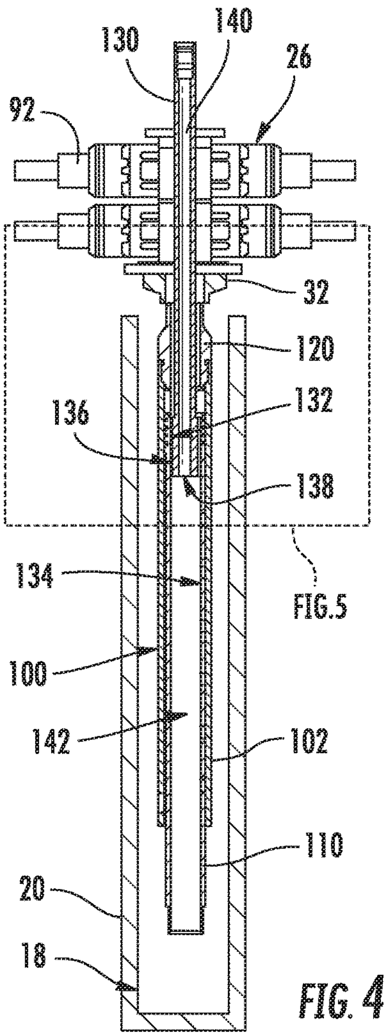


FIG. 4

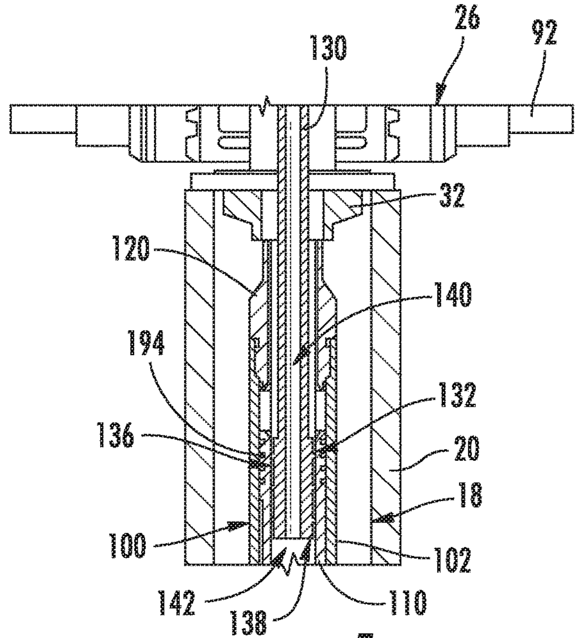


FIG. 5

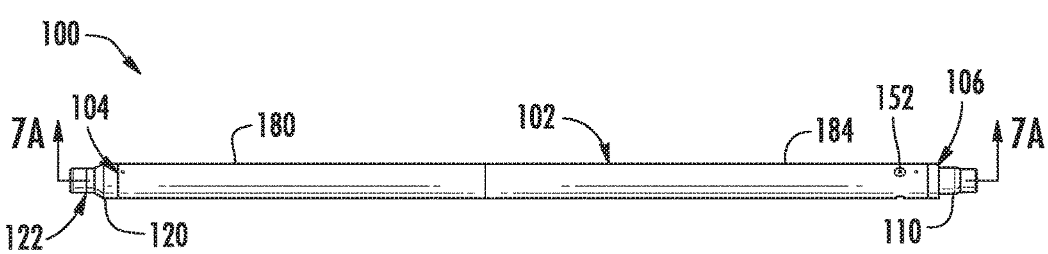


FIG. 6

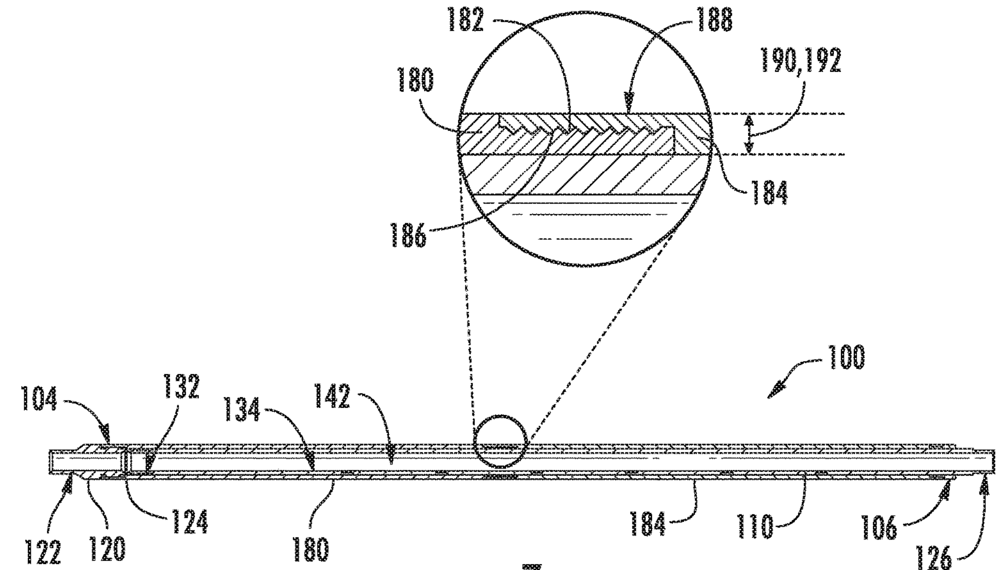

182
188
180
190,192
184
186
100
104
132
134
142
122
120
124
180
184
110
106
126

FIG. 7

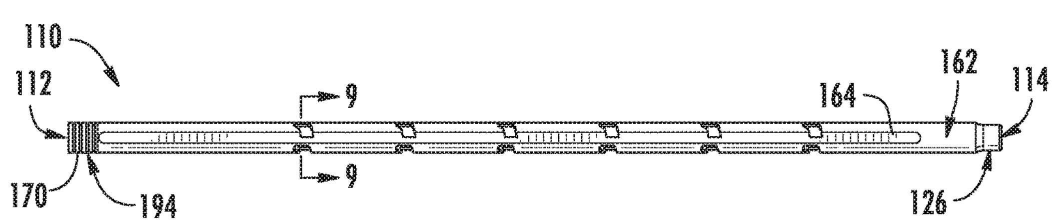

110
112
9
162
164
114
9
170
194
126

FIG. 8

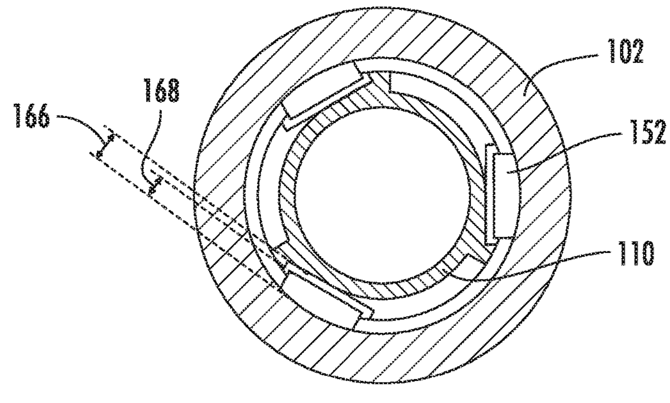


FIG. 9

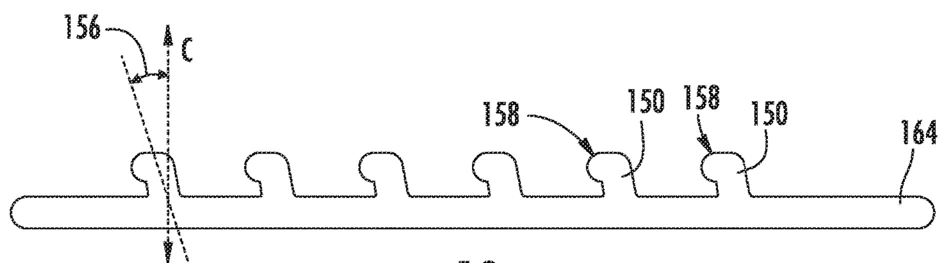


FIG. 10

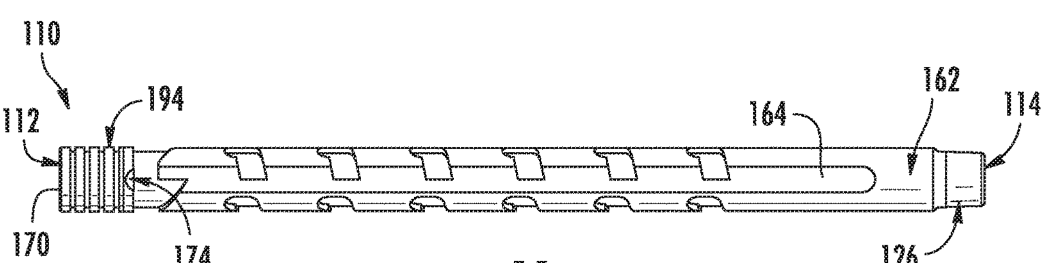


FIG. 11

APPARATUS FOR AXIALLY DISPLACING AND TENSIONING A STRING OF PRODUCTION TUBING IN A WELL BORE

FIELD OF THE INVENTION

[0001] The present subject matter relates generally to the handling of downhole well tools and production tubing strings, and more particularly to axially displacing or placing in tension a production tubing string.

BACKGROUND OF THE INVENTION

[0002] Downhole operations and the handling of downhole well tools in completed wells has always presented a certain challenge, especially when working in wells having a natural pressure that is different than atmospheric pressure, necessitating the containment of the well at all times. A further challenge has been the maintenance of well bores which pass through production zones that are not well suited to continuous production. For example, conventional maintenance operations of a well having a production zone which yields both water and oil, gas, or any combination thereof has proven time-consuming and expensive.

[0003] For example, in wells which have a mobile water/hydrocarbon interface, the production of hydrocarbon gradually decreases over time until only water or gas is produced from the well. Such wells may require relatively frequent repositioning of a lower end of a string of production tubing in order to recover oil or gas efficiently. The relocation of the tubing string has been a complex process which involved many time-consuming and expensive steps that are well known in the art. It is not difficult to appreciate that there is a need for a more efficient and less costly system for producing oil or gas from such wells.

[0004] In addition, as technology has advanced and well operations have resulted in deeper or longer well bores, the length of the corresponding string of production tubing has also increased—along with the weight of such production tubing. Manipulating such a tubing string can result in operational difficulties. For example, moving a tubing string of 4,500' (1,500 meters), which is not uncommonly encountered in handling downhole well tools, may require a force in excess of 50 tons. The force required is due not only to the considerable weight being lifted but also to the extra force required to unseat anchors and/or packers supporting the tubing string. Such forces may subject the wellhead to potentially damaging stresses. Notably, conventional mechanisms for manipulating these tubing strings may include a spear and grapple assembly which may not be sufficient to support the higher loads associated with longer tubing strings. Moreover, conventional spears assemblies provide no means for assisting with well pressure control, e.g., in the presence of a blowout condition.

[0005] Furthermore, it is often desirable to place long strings of production tubing in tension, e.g., to prevent damage due to compression corkscrewing, to provide a relatively straight tubing string for easy and safe manipulation of downhole tools, etc. Conventional tensioning tools have a fixed length or stroke that may be sufficient for accommodating tubing stretch and tensioning tubing strings in relatively shallow wells. However, as well operations get deeper and their associated production tubing strings get longer, such tools often fail to allow for sufficient axial displacement, e.g., to accommodate the tubing stretch associated with the longer tubing string or to facilitate necessary downhole operations.

[0006] There therefore exists a need for an apparatus which enables downhole manipulations such as placing a string of production tubing, anchors, or other downhole tools in tension while facilitating improved control of well pressure to eliminate the potential for loss of control.

[0007] BRIEF DESCRIPTION OF THE INVENTION

[0008] The present disclosure relates generally to a tensioning tool assembly for supporting a string of oil production piping extending through a well bore. The tensioning tool assembly includes an outer barrel and a telescoping inner mandrel slidably positioned within the outer barrel. The inner mandrel defines a plurality of axially-spaced slots configured to receive protruding members extending from the outer barrel to fix the relative axial position of the inner mandrel and outer barrel. In this manner, a string of production tubing may be axially displaced by moving inner mandrel to the desired axial position or tension and then rotating inner mandrel to lock the tensioning tool assembly and the attached production tubing. The inner mandrel may further define threaded features for attaching a pull rod and/or a central passageway for supplying fluid to control well pressures. Additional aspects and advantages of the invention will be set forth in part in the following description, or may be apparent from the description, or may be learned through practice of the invention.

[0009] In one exemplary embodiment, a tensioning tool assembly for supporting a string of oil production piping extending through a well bore is provided. The tensioning tool includes an outer barrel defining an axial direction, a radial direction, and a circumferential direction, the outer barrel extending between an upper end and a lower end along the axial direction. A telescoping inner mandrel is slidably positioned within the outer barrel and extends between a first end and a second end along the axial direction. The inner mandrel defines a coupling feature configured for engaging a complementary feature defined on a pull rod such that the pull rod is configured for selectively engaging and moving the inner mandrel along the axial direction.

[0010] In another exemplary embodiment, a tensioning tool assembly for supporting a string of oil production piping extending through a well bore is provided. The tensioning tool includes an outer barrel defining an axial direction, a radial direction, and a circumferential direction. The outer barrel includes a first barrel defining a male threaded portion and a second barrel defining a female threaded portion, the male threaded portion and the female threaded portion being engaged to join the first barrel and the second barrel. A telescoping inner mandrel is slidably positioned within the outer barrel and extends between a first end and a second end along the axial direction. The inner mandrel defines a coupling feature configured for engaging a complementary feature defined on a pull rod such that the pull rod is configured for selectively engaging and moving the inner mandrel along the axial direction.

[0011] These and other features, aspects and advantages of the present invention will become better understood with reference to the following description and appended claims. The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] A full and enabling disclosure of the present invention, including the best mode thereof, directed to one of ordinary skill in the art, is set forth in the specification, which makes reference to the appended figures.

[0013] FIG. **1** provided a cross-sectional view of a rig apparatus including a tensioning tool assembly according to an exemplary embodiment of the present subj ect matter.

[0014] FIG. **2** provides a front view of the exemplary tensioning tool assembly of FIG. **1** according to an exemplary embodiment of the present subject matter.

[0015] FIG. **3** provides a front, cross-sectional view of the exemplary tensioning tool assembly of FIG. **1** according to an exemplary embodiment of the present subject matter.

[0016] FIG. **4** provides a cross-sectional view of a rig apparatus including a tensioning tool assembly and a pull rod for engaging an inner mandrel of the exemplary tensioning tool assembly according to an exemplary embodiment of the present subject matter.

[0017] FIG. **5** provides a close up cross-sectional view of the pull rod engaging the inner mandrel according to an exemplary embodiment of the present subject matter.

[0018] FIG. **6** provides a front view of a tensioning tool assembly that may be used in the exemplary rig apparatus of FIG. **1** according to an exemplary embodiment of the present subject matter.

[0019] FIG. **7** provides a front, cross-sectional view of the exemplary tensioning tool assembly of FIG. **6** according to an exemplary embodiment of the present subject matter.

[0020] FIG. **8** provides a front view of an inner mandrel of the exemplary tensioning tool assembly of FIG. **6** according to an exemplary embodiment of the present subject matter.

[0021] FIG. **9** provides a cross-sectional view of the exemplary inner mandrel of FIG. **8**, taken along Line **9-9** of FIG. **8**.

[0022] FIG. **10** provides a schematic view of an elongated flat recess and a plurality of slots defined by the exemplary inner mandrel of FIG. **8**.

[0023] FIG. **11** provides a front view of an inner mandrel according to another exemplary embodiment of the present subject matter.

[0024] Repeat use of reference characters in the present specification and drawings is intended to represent the same or analogous features or elements of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0025] Reference now will be made in detail to embodiments of the invention, one or more examples of which are illustrated in the drawings. Each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope or spirit of the invention. For instance, features illustrated or described as part of one embodiment can be used with another embodiment to yield a still further embodiment. Thus, it is intended that the present invention covers such modifications and variations as come within the scope of the appended claims and their equivalents.

[0026] The present disclosure relates generally to an apparatus for performing downhole operations in well bores which require axial displacement of downhole tools and/or axial displacement of a string of production or well tubing in the well bore. In addition, the present disclosure provides a practical means for maintaining tension or compression on a tubing string in the well bore. Although rig apparatus **64** and a string of production tubing **40** are used below for the purpose of explaining the details of the present subject matter, one skilled in the art will appreciate that the present subject matter may apply to any other suitable oil rig or production tubing configuration. Rig apparatus **64** is used in the discussion below only for the purpose of explanation, and such use is not intended to limit the scope of the present disclosure in any manner.

[0027] FIG. **1** shows a cased well bore which passes through a production zone **10** that produces water **12**, oil **14**, and natural gas **16**. The cased well bore consists of a bore generally indicated by reference numeral **18** lined with a casing **20** in a manner well known in the art. A wellhead generally indicated by reference **26** is mounted to a surface casing spool **28**. A tubing spool **30** supports a tubing hanger **32** also in a manner well known in the art.

[0028] FIG. **1** also illustrates a string of production tubing **40** that is generally configured for extending between wellhead **26** and production zone **10**, e.g., to transport well production to the surface. As illustrated, production tubing **40** includes a zone isolating tool generally indicated by the reference **42** located at a bottom of production tubing **40**. In accordance with a preferred embodiment of the invention, the zone isolating tool **42** is assembled using packer cups **44**. Packer cups **44** may be, for example, packer cups commercially available packer cups that are assembled in a sequence similar to that of a selective acidizing tool known in the art with the exception that two extra cups are added and an upper cup **44***a* is oriented upwardly and a lower cup **44***f* is oriented downwardly. It should also be understood by those skilled in the art that the two groups of cups **44***a*-**44***c* and **44***d*-**44***f* may be replaced by straddle packers (not illustrated) or inflatable packers (not illustrated) while still achieving substantially the same utility.

[0029] Intermediate between the groups of cups **44***a*-**44***c* and **44***d*-**44***f* is an isolated fluid zone **46** which is isolated by the cups or packers from the remainder of a cased well bore when the production tubing **40** is inserted into well bore **18**. At least one bore **48** enables fluid communication between an interior of production tubing **40** and the isolated fluid zone **46**. Bore **48** may be replaced by a sleeve valve or the like according to alternative embodiments. A bottom end of the zone isolating tool **42** includes a profile nipple (not illustrated) which supports a plug **50** or a control valve (not illustrated).

[0030] According to an exemplary embodiment, zone isolating tool **42** is preferably positioned in production zone **10** so that at least the isolated fluid zone **46** is in the zone of interest, namely the oil "sandwich" **14**. The downward facing cups **44***b* and **44***c* and the upward facing cups **44***d* and **44***e* isolate pressure from the oil sandwich **14** to prevent oil from being forced upwardly or downwardly out of the isolated fluid zone **46** so that oil in the casing is contained within the isolated fluid zone **46**. The upward facing cup **44***a* prevents gas from being forced down through casing **20** to enter production tubing **40**. While some gas may enter perforations that happen to be located between cups **44***a* and

44*c* and that gas may force past cup **44***e* into the isolated fluid zone **46**, the amount of gas entering the isolated fluid zone **46** will be minimal. Likewise, while downward facing cup **44***f* will prevent most water from the water zone **12** from entering the isolated fluid zone **46**, some water may seep through perforations located between cups **44***f* and **44***d*. A minimal amount of water may therefore be forced into the isolated fluid zone **46** but most water will be excluded by the downward facing cup **44***f* and predominantly only oil will be produced through the production tubing **40**.

[0031] Notably, as oil is produced from the oil sandwich **14**, the water layer **12** typically rises. As the water layer **12** rises, an interface between the oil sandwich **14** and the water layer **12** also rises. This permits water to enter the isolated fluid zone **46** and be produced with the oil **14**. As will be explained with reference to FIG. **2**, production tubing **40** includes a telescoping joint, referred to herein as tensioning tool assembly **100**, which is configured for joining production tubing **40** to wellhead **26**. More specifically, according to an exemplary embodiment of the present subject matter, tensioning tool assembly **100** is located at or near a top of the string of production tubing **40** and is coupled to tubing hanger **32**. As will be discussed in more detail below, tensioning tool assembly **100** is used to raise production tubing **40** in order to adjust the position of isolated fluid zone **46** in response to the change in position of the oil/water interface or to otherwise axially displace production tubing **40** to achieve the desired tension.

[0032] Tensioning tool assembly **100** may be attached directly to tubing hanger **32** or may be attached to tubing hanger **32** by a "pup" joint **54** of production tubing. Alternatively, either the tensioning tool assembly **100** or the pup joint or tubing joints **54** may be connected directly to wellhead **26** in a manner well known in the art. When tensioning tool assembly **100** is used for repositioning production tubing **40**, it is preferable that a length of travel "A" of tensioning tool assembly **100** is substantially equal to the length "B" of a perforated zone or production zone **10** of potential producing intervals of the casing **20** to permit downhole tools to be positioned anywhere within the perforated zone or zones of interest. In a typical production installation such as shown in FIG. **1**, a production packer **56** is located above production zone **10** to isolate the zone from the pressure of gas injected into the annulus of casing **20** to lift oil produced from the oil sandwich **14** to a surface of the well using gas-lift mandrels **58** positioned at intervals along production tubing **40** in a manner well known in the art. Compression anchors **60** help support the compression load of the string of production tubing **40** and prevent damage due to compression corkscrewing and the like. It will also be understood by those skilled in the art that oil may be produced through production tubing equipped with apparatus in accordance with the invention using a pump such as a submersible pump, a progressive cavity pump or the like, or artificial lift or injection systems.

[0033] It will be readily understood by persons skilled in the art that the packer cups **44***a*-**44***f* may be replaced by other fluid isolation apparatus such as straddle packers, or inflatable packers, as described above. In order to selectively produce, inject, or stimulate a predominance of a fluid of interest it is only necessary that isolated fluid zone **46** be created by sealing the annulus of casing **20** at or near each interface of the fluid of interest and that the zone isolating tool **42** be axially displaceable so that it is readily repositionable within the well bore **18** to permit the zone isolating tool **42** to be relocated as required to produce a predominance of the fluid of interest.

[0034] Referring still to FIG. **1**, a rig apparatus **64** is installed over wellhead **12** and is generally configured for assisting with well operations according to an exemplary embodiment. More specifically, for example, rig apparatus **64** is bolted to a top of the wellhead **26** and may include adjustable support pads **66** located respectively at the base of each support leg **68** which may be adjusted so that rig apparatus **64** is level and support legs **68** share the load to be placed on the rig apparatus **64**, e.g., when supporting the string of production tubing **40**.

[0035] According to the illustrated embodiment, a lower support plate **70** is attached to or otherwise supported by support legs **68** to reduce compressive and torsional forces on wellhead **26** which may be induced by the lifting and manipulation of heavy strings of production tubing **40**. Located above lower support plate **70** is an upper support plate **72** which is also supported by support legs **68**. Reciprocally moveable between lower support plate **70** and upper support plate **72** is a traveling support plate **74**. When mounted on support legs **68**, traveling support plate **74** is prevented from rotating. Affixed to traveling support plate **74** is a motor **76** that is selectively operated to rotate a lift rod string **80**. The motor **76** (or any other suitable lift mechanism) may be a hydraulic motor, an electric motor, or any other suitable mechanical means (such as a rig apparatus) for example.

[0036] According to an exemplary embodiment, the stator of motor **76** is mounted to the traveling support plate **74** and the rotor is connected to lift rod string **80**, e.g., via a link rod, swivel joint, etc. Lift rod string **80** may further be connected with a piston rod **82** of a hydraulic cylinder **84** which is mounted to upper support plate **72**. In this manner, hydraulic cylinder **84** provides the motive of force for displacing lift rod string **80** (and the string of production tubing **40** to which it is attached) along an axial direction A. Although motor **76** is described herein as being used to rotate production tubing **40**, it should be appreciated that any other suitable means for rotating production tubing **40** or any other downhole tools are possible and within the scope of the present subject matter.

[0037] Typically, wellhead **12** includes one or more spools, e.g., such as a surface spool and a master valve spool (not shown), the structure of each being well known in the art. According to an illustrated embodiment, mounted to a top of the uppermost part of wellhead **12** is a tool entry spool **86**, which is the lowermost component of rig apparatus **64**. Tool entry spool **86** accommodates a latch tool **88** for connecting a lift rod string **80** to a latch point **90** of tensioning tool assembly **100**, directly to a production tube **40**, or other downhole tubular when the lift rod string **80** is run into well bore **18**.

[0038] According to the illustrated embodiment, an annular seal for containing well pressure is mounted to a top flange of tool entry spool **86**. For example, according to the illustrated embodiment, the annular seal includes one or more blowout preventers **92**. As will be understood by those skilled in the art, other annular seals for containing well pressure can be adapted for use with rig apparatus **64**. For example, certain stuffing box structures or multiple ram type or annular preventers can be adapted for such use. Blowout preventer **92** is preferred, however, because of the ease of use and the security of the seal it provides. Preferably, the apparatus includes two blowout preventers **92** connected in sequence in order to increase the safety of the apparatus and to provide extra room between the master valve spool and the uppermost blowout preventer **92** to accommodate latch tools **88** of different lengths. With two or more blowout preventers safety is increased because the preventers can be opened and closed in sequence at each lift rod joint connector in the lift rod string to prevent tears in sealing surfaces which can result from forcing rough surfaces at the connectors through a closed preventer. For this reason, it is preferable that the adjacent preventers be spaced about 10-13 cm (4"-5") apart to accommodate a lift rod joint connector between them.

[0039] Mounted to a top of the uppermost blowout preventer **92** is a tool access spool **94** having at least one tool window **96** or an integral locking mechanism (not illustrated). The tool window **96** permits gripping or locking devices to be inserted for engaging lift rod string **80**. In general, tool window **96** permits the lift rod string **80** to be gripped to permit joints to be added to, or removed from, the lift rod string **80**. It also permits the lift rod string **80** to be locked against axial movement when joints are being added to, or removed from, the lift rod string **80**. For example, the weight of the string of production tubing **40** can be supported at the tool window **96** in low pressure wells while lift rod string joints are being added, or removed. If wells with exceptionally high pressure are being worked, a lock inserted through the tool window **96** prevents the lift rod string **80** from being forced up out of well bore **18** while joints are being added to, or removed from, lift rod string **80**.

[0040] Referring now generally to FIGS. **2** through **9**, tensioning tool assembly **100** will be described according to an exemplary embodiment of the present subject matter. As explained briefly above, tensioning tool assembly **100** may generally be used for supporting a string of oil production piping, such as production tubing **40**, for axially displacing downhole tools within the well bore, or for placing the string of production tubing **40** in tension or compression. It should be appreciated that aspects of the present subject matter can be utilized for performing other well operations and tensioning tool assembly **100** is only one exemplary embodiment of an apparatus for performing such functions.

[0041] As illustrated, tensioning tool assembly **100** includes an outer barrel **102** that defines an axial direction A, a radial direction R, and a circumferential direction C. Outer barrel **102** extends along the axial direction A between an upper end **104** and an opposite lower end **106**. A telescoping inner mandrel **110** is slidably positioned within outer barrel **102** such that inner mandrel **110** is movable along the axial direction A relative to outer barrel **102**. More specifically, inner mandrel **110** extends along the axial direction A between a first end **112** and a second end **114**. Inner mandrel **110** may telescope or slide relative to outer barrel **102** between a retracted position where inner mandrel **110** is positioned substantially within outer barrel **102** and an extended position where inner mandrel **110** is positioned substantially outside outer barrel **102**. More specifically, first end **112** of inner mandrel **110** is positioned proximate upper end **104** of outer barrel **102** in the retracted position and proximate lower end **106** of outer barrel **102** in the extended position.

[0042] As best illustrated in FIG. **3**, tensioning tool assembly **100** may further include a hanger adapter **120** positioned proximate upper end **104** of outer barrel **102** for joining tensioning tool assembly **100** to a wellhead. For example, hanger adapter **120** may define a threaded top surface **122** (threads not illustrated) configured for receipt within tubing hanger **32** of wellhead **26**. According to the illustrated exemplary embodiment, hanger adapter **120** is joined to outer barrel **102** via a threaded connection **124**. However, it should be appreciated that according to alternative embodiments, hanger adapter **120** may be coupled to tubing hanger **32** and outer barrel in any other suitable manner. For example, hanger adapter **120** may be formed integrally with outer barrel **102** and may have threads machined on an inner or outer surface.

[0043] Referring now specifically to FIGS. **2** and **3**, second end **114** of inner mandrel **110** may define features for engaging production tubing **40**. More specifically, according to the illustrated embodiment, second end **114** of inner mandrel **110** defines a threaded bottom surface **126** (threads not illustrated) for engaging the top tube of a string of production tubing **40**. In this manner, as inner mandrel **110** moves along the axial direction A within outer barrel **102**, the string of production tubing **40** and/or attached well bore tools can be moved axially within the well bore **18** to achieve various purposes as described herein.

[0044] Inner mandrel **110** may define one or more features for engaging a spear, a pull rod, or another tool for moving inner mandrel **110** within outer barrel **102**. For example, referring now briefly to FIGS. **4** and **5**, a pull rod **130** may be passed through wellhead **26** and may be configured for engaging inner mandrel **110**. In this manner, pull rod **130** may be coupled to rig apparatus **64** for pulling the string of production tubing **40** to the desired tension, compression, or position. In general, inner mandrel **110** defines a coupling feature configured for engaging a complementary feature defined on pull rod **130** such that pull rod **130** is configured for selectively engaging and moving inner mandrel **110** along the axial direction A. More specifically, according to the illustrated embodiment, the coupling feature comprises mandrel threads **132** defined on an inner surface **134** of inner mandrel **110** and the complementary feature comprises pull rod threads **136** defined on a distal end **138** of pull rod **130**.

[0045] Therefore, pull rod **130** may pass into tensioning tool assembly **100** through outer barrel **102** and may be rotated such that pull rod threads **136** engage mandrel threads **132**. Once pull rod **130** is engaged, the relative axial and circumferential positioning of pull rod **130** and inner mandrel **110** are fixed, i.e., such that pull rod **130** may be used to place tension on inner mandrel **110** and production tubing **40**. Although a threaded pull rod **130** is described herein, it should be appreciated that any suitable apparatus for selectively engaging and disengaging inner mandrel **110** for supporting the weight of production tubing **40** may be used according to alternative embodiments.

[0046] According to the illustrated embodiment, pull rod **130** engages inner mandrel **110** using a threaded connection. However, it should be appreciated that pull rod **130** may be releasably attached to inner mandrel **110** using any other suitable latch mechanism which may include quick-disconnect threads, spears, grapples, keys, collets, friction or slip type tools, releasable packers or rotary taper taps. Once pull rod **130** engages inner mandrel **110**, tensioning tool assembly **100** permits the axial displacement of production tubing **40** and the zone isolating tool **42** (or another downhole tool) in the casing **20**. This permits a variety of downhole tool manipulations to accomplish various tasks without setting up a derrick or bringing in a crane, killing the well or performing many of the other steps required using prior art methods. Moreover, according to aspects of the present subject matter, tensioning tool assembly **100** may further be used to move a string of production tubing **40** to place it in tension, compression, or to otherwise rotate or move production tubing **40**.

[0047] Pull rod **130** may also include features for controlling well pressures. For example, according to the illustrated embodiment of FIGS. **4** and **5**, pull rod **130** defines a central passageway **140** in fluid communication with an internal passageway **142** of inner mandrel **110**. Using this central passageway **140**, a well operator may pump a drilling fluid or mud through central passageway **140**, into internal passageway **142**, and through production tubing **40** to control pressures within well bore **18**. It should be appreciated that according to alternative embodiments, pull rod may not define a central passageway for pumping fluids.

[0048] Referring now to FIGS. **8** through **10**, outer barrel **102** and inner mandrel **110** may further define one or more features for locking the inner mandrel **110** relative to the outer barrel **102**. In this manner, for example, the string of production tubing **40** may be pulled to the desired tension (as described above) and locked in tension. For example, according to the illustrated embodiment, inner mandrel **110** defines a plurality of slots **150** spaced apart along the axial direction A, each of the slots **150** extending substantially along the circumferential direction C around inner mandrel **110**. It should be appreciated that as used herein, terms of approximation, such as "approximately," "substantially," or "about," refer to being within a ten percent margin of error. In addition, outer barrel **102** defines one or more protruding members **152** (see FIG. **9**) such as bosses or lug nuts that extend inward along the radial direction R from outer barrel **102** toward inner mandrel **110**. In general, protruding members **152** are configured for engaging one or more of slots **150** to lock the axial position of inner mandrel **110** within outer barrel **102**.

[0049] More specifically, according to the illustrated embodiment, the plurality of slots **150** include six sets of slots **150**, each set being spaced apart by approximately **12** centimeters along the axial direction A. For simplicity, only one set of slots **150** is illustrated schematically in FIG. **10**. However, it should be appreciated that each set of slots **150** may include any suitable number of circumferentially spaced slots **150** and a corresponding number of protruding members **152** according to alternative embodiments. For example, the illustrated embodiment includes three circumferentially spaced slots **150** for engaging three circumferentially spaced protruding members **152** defined on outer barrel **102**. It should be appreciated that the slots **150** and protruding members **152** illustrated herein are used only for the purpose of explaining aspects of the present subject matter and are not intended to be limiting. For example, although six axially spaced slots **150** are illustrated, it should be appreciated that any suitable number, spacing, geometry, and configuration of slots may be used according to alternative embodiments. For example, inner mandrel **110** may define **10**, **100**, or any other suitable number of slots **150**.

[0050] FIG. **8** illustrates a schematic view of potential sliding paths of protruding members **152** along inner mandrel **110**. As illustrated, slots **150** extend at an angle **156** relative to the circumferential direction C. More specifically, angle **156** may be between about 0 and 30 degrees, between about 5 and 15 degrees, about 10 degrees, or may be any other suitable angle. In addition, each of slots **150** may have a closed end for stopping the rotate of inner mandrel **110**. As illustrated in FIG. **10**, slots **150** may be J-shaped slots that define an axial recess **158** for ensuring engagement with protruding member **152**. Alternatively, slots **150** may be formed to have any suitable shape and configuration.

[0051] Notably, the inner diameter of outer barrel **102** is substantially similar or slightly larger than the outer diameter of inner mandrel **110**. To allow inner mandrel **110** to slide within outer barrel **102**, an outer surface **162** of inner mandrel **110** defines an elongated flat recess **164** between the axially spaced-apart slots **150** to provide a path of travel for protruding members **152**. More specifically, elongated flat recess **164** is used to define a radial gap **166** between inner mandrel **110** and outer barrel **102**, as best shown in FIGS. **8** through **11**. In this manner, protruding members **152** may be positioned within radial gap **166** and slide axially along elongated flat recess **164** to allow inner mandrel **110** to slide within outer barrel **102**. More specifically, for example, protruding members **152** define a height **168** that is less than the height of radial gap **166** such that inner mandrel **110** is slidable along the axial direction A relative to outer barrel **102** when the protruding members **152** are positioned within radial gap **166**.

[0052] When inner mandrel **110** is pulled to an axial position where protruding members **152** are at the same axial position as a set of slots **150**, inner mandrel **110** may be rotated to position protruding members **152** within those slots **150** and lock the axial position of inner mandrel **110**. According to the illustrated embodiment, protruding members **152** are positioned proximate lower end **106** of outer barrel **102** to permit inner mandrel **110** to reach a fully extended position before mandrel head **170** engages protruding members **152** to retain inner mandrel **110** within outer barrel **102**.

[0053] According to an exemplary embodiment of the present subject matter, tensioning tool assembly **100** may further define features for locking the angular position of inner mandrel **110** within outer barrel **102** when inner mandrel **110** is in the fully extended position. More specifically, according to the illustrated embodiment of FIG. **11**, inner mandrel **110** defines one or more locking recesses **174** proximate first end **112** of inner mandrel **110**. Locking recesses **174** may be, for example, semicircular cutouts defined in mandrel head **170** that are configured for engaging protruding members **152** when inner mandrel **110** is in the extended position. In this manner, when protruding members **152** are engaged within locking recesses **174**, the relative angular position of inner mandrel **110** and outer barrel **102** are fixed, such that inner mandrel **110** and production tubing **40** may be rotated by rotating outer barrel **102**. It should be appreciated that other mechanisms for fixing the angular position of inner mandrel **110** relative to outer barrel **102** are possible and within the scope of the present subject matter.

[0054] Referring now to FIGS. **6** and **7**, outer barrel **102** may include any suitable number of segments or barrels coupled together to form tensioning tool assembly **100** having a suitable axial length and extension length desirable for a particular application. For example, according to the illustrated embodiments, outer barrel **102** includes a first barrel **180** defining a male threaded portion **182** and a second barrel **184** defining a female threaded portion **186**. As illustrated, male threaded portion **182** and female threaded portion **186** are engaged to form a joint **188** that couples first barrel **180** and second barrel **184**. According to the illustrated embodiment, joint **188** defines a joint thickness **190** that is substantially equal to a wall thickness **192** of first barrel **180** and second barrel **184**. In this manner, joint **188** is smooth and includes no irregularities that may prevent inner mandrel **110** from sliding smoothly within outer barrel **102**.

[0055] In order to prevent leaks between production zone **10** and wellhead **26**, tensioning tool assembly **100** is preferably a fluid tight assembly. In this regard, referring for example to FIGS. **3** and **8**, inner mandrel **110** defines one or more circumferential grooves **194** on an outer surface **162** proximate first end **112** of inner mandrel **110**. Tensioning tool assembly **100** further includes one or more resilient annular seals **196**, e.g., O-rings, positioned within circumferential grooves **194** to provide a fluid seal between inner mandrel **110** and outer barrel **102**. Annular seals **196** are preferably high pressure fluid seals to ensure that high pressure fluids do not escape from tensioning tool assembly **100**. In this manner, hydrocarbons, drilling mud, and/or other fluids may not leak out of tensioning tool assembly **100** as inner mandrel **110** moves between the extended and retracted positions.

[0056] Tensioning tool assembly **100** described above provides an effective means of axially displacing or tensioning a string of production tubing within a well bore. A long production tubing string tends to sag under its own weight. This is disadvantageous if a surface-driven reciprocating pump is used to recover hydrocarbons from the well. Such tubing strings may be anchored at their bottom end by an anchor member, such as a packer connected to the bottom of the production tubing string. A top of the production tubing string includes tensioning tool assembly **100** connected to a tubing hanger in a wellhead. A lifting mechanism is temporarily installed on the wellhead to enable tensioning tool assembly **100** to be retracted until the tubing string is under a desired tension to prevent undesirable sag as hydrocarbon is produced from the well.

[0057] Using tensioning tool assembly **100** for tensioning a production tubing string advantageously simplifies the conventional method in which a pup joint having a desired length has to be prepared to replace a top production tubing joint. As is well known, it is a time-consuming, expensive and potentially hazardous operation to determine a required length for the pup joint, and to install it. However, with a locking tensioning tool assembly **100** in accordance with the present subject matter, the operation is quickly, easily, and inexpensively done without removing the wellhead and without the dangers of moving tubing that is under pressure or working over an open well bore. Tensioning tool assembly **100** also permits the tubing string to be re-tensioned without removing the wellhead or killing the well if, over time, the tubing string loses its tension.

[0058] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they include structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed is:

1. A tensioning tool assembly for supporting a string of oil production piping extending through a well bore, the tensioning tool comprising:

- an outer barrel defining an axial direction, a radial direction, and a circumferential direction, the outer barrel extending between an upper end and a lower end along the axial direction; and
- a telescoping inner mandrel slidably positioned within the outer barrel, the inner mandrel extending between a first end and a second end along the axial direction, the inner mandrel defining a coupling feature configured for engaging a complementary feature defined on a pull rod such that the pull rod is configured for selectively engaging and moving the inner mandrel along the axial direction.

2. The tensioning tool assembly of claim **1**, wherein the coupling feature comprises mandrel threads defined on an inner surface of the inner mandrel and the complementary feature comprises pull rod threads defined on a distal end of the pull rod.

3. The tensioning tool assembly of claim **1**, wherein the pull rod defines a central passageway in fluid communication with an internal passageway of the inner mandrel.

4. The tensioning tool assembly of claim **1**, wherein the relative axial positioning and the relative circumferential positioning of the pull rod and the inner mandrel are fixed when the coupling feature engages the complementary feature.

5. The tensioning tool assembly of claim **1**, wherein the outer barrel comprises:

- a first barrel defining a male threaded portion; and
- a second barrel defining a female threaded portion, the male threaded portion and the female threaded portion being engaged to join the first barrel and the second barrel.

6. The tensioning tool assembly of claim **5**, wherein a joint is defined where the male threaded portion engages the female threaded portion, the joint defining a joint thickness that is substantially equal to a wall thickness of the first barrel and the second barrel.

7. The tensioning tool assembly of claim **1**, wherein the inner mandrel defines one or more circumferential grooves on an outer surface proximate the first end of the inner mandrel, the tensioning tool assembly further comprising one or more resilient seals positioned within the circumferential grooves to provide a fluid seal between the inner mandrel and the outer barrel.

8. The tensioning tool assembly of claim **1**, wherein the inner mandrel defines a plurality of slots extending substantially along the circumferential direction around the inner mandrel, the plurality of slots being spaced apart along the axial direction, and wherein the outer barrel defines one or more protruding members proximate the lower end of the outer barrel, the protruding members being configured for receipt within the slots to fix an axial position of the inner mandrel within the outer barrel.

9. The tensioning tool assembly of claim **8**, wherein the plurality of slots extend at an angle relative to the circumferential direction.

10. The tensioning tool assembly of claim **9**, wherein the angle is between about 1 and 20 degrees.

11. The tensioning tool assembly of claim **8**, wherein an outer surface of the inner mandrel defines an elongated flat recess to define a radial gap between the inner mandrel and the outer barrel, the protruding members defining a height that is less than the radial gap such that the inner mandrel slidable along the axial direction relative to the outer barrel when the protruding members are positioned within the radial gap.

12. The tensioning tool assembly of claim **11**, wherein the inner mandrel defines one or more locking recesses proximate the first end of the inner mandrel, the locking recesses being configured for engaging the protruding members to prevent the inner mandrel from rotating within the outer barrel.

13. The tensioning tool assembly of claim **8**, wherein the plurality of slots comprises six slots, each of the six slots being spaced apart from adjacent slots by approximately 12 centimeters along the axial direction.

14. The tensioning tool assembly of claim **1**, wherein the upper end of the outer barrel is threaded for receipt in a tubing hanger mounted to a wellhead.

15. A tensioning tool assembly for supporting a string of oil production piping extending through a well bore, the tensioning tool comprising:

an outer barrel defining an axial direction, a radial direction, and a circumferential direction, the outer barrel comprising a first barrel defining a male threaded portion and a second barrel defining a female threaded portion, the male threaded portion and the female threaded portion being engaged to join the first barrel and the second barrel; and

a telescoping inner mandrel slidably positioned within the outer barrel, the inner mandrel extending between a first end and a second end along the axial direction, the inner mandrel defining a coupling feature configured for engaging a complementary feature defined on a pull rod such that the pull rod is configured for selectively engaging and moving the inner mandrel along the axial direction.

16. The tensioning tool assembly of claim **15**, wherein a joint is defined where the male threaded portion engages the female threaded portion, the joint defining a joint thickness that is substantially equal to a wall thickness of the first barrel and the second barrel.

17. The tensioning tool assembly of claim **15**, wherein the coupling feature comprises mandrel threads defined on an inner surface of the inner mandrel and the complementary feature comprises pull rod threads defined on a distal end of the pull rod, and wherein the relative axial positioning and the relative circumferential positioning of the pull rod and the inner mandrel are fixed when the pull rod threads engage the mandrel threads.

18. The tensioning tool assembly of claim **15**, wherein the pull rod defines a central passageway in fluid communication with an internal passageway of the inner mandrel.

19. The tensioning tool assembly of claim **15**, wherein the inner mandrel defines one or more circumferential grooves on an outer surface proximate the first end of the inner mandrel, the tensioning tool assembly further comprising one or more resilient seals positioned within the circumferential grooves to provide a fluid seal between the inner mandrel and the outer barrel.

20. The tensioning tool assembly of claim **15**, wherein the inner mandrel defines a plurality of slots extending substantially along the circumferential direction around the inner mandrel, the plurality of slots being spaced apart along the axial direction, and wherein the outer barrel defines one or more protruding members proximate a lower end of the outer barrel, the protruding members being configured for receipt within the slots to fix an axial position of the inner mandrel within the outer barrel.

* * * * *