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(54) **TUBING HANGER WITH ANNULUS BORE**

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E21B 33/068 (2006.01)

(52) **U.S. Cl.**
USPC **166/348**; 166/368; 166/344

(58) **Field of Classification Search**
USPC 166/335, 344, 338, 348, 360, 363–365, 166/368, 225
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,889,886	A *	6/1959	Gould	166/89.3
3,602,303	A *	8/1971	Blenkarn et al.	166/360
4,887,672	A *	12/1989	Hynes	166/344
4,903,774	A *	2/1990	Dykes et al.	166/363
5,114,158	A *	5/1992	Le	277/314
5,143,158	A *	9/1992	Watkins et al.	166/344
5,372,199	A *	12/1994	Cegielski et al.	166/368
5,535,826	A *	7/1996	Brown et al.	166/363
5,544,707	A *	8/1996	Hopper et al.	166/382
5,575,336	A *	11/1996	Morgan	166/330
5,687,794	A *	11/1997	Watkins et al.	166/363
5,941,310	A *	8/1999	Cunningham et al.	166/345
5,992,527	A *	11/1999	Garnham et al.	166/379
6,039,119	A *	3/2000	Hopper et al.	166/368

(Continued)

FOREIGN PATENT DOCUMENTS

GB	2192921 A	1/1988
WO	WO 00/47864	8/2000

(Continued)

OTHER PUBLICATIONS

SPE 23145; Sanders, R.O., *Installation of Concentric Subsea Completions From a Jack-Up in the Welland Field: A Case History,* Society of Petroleum Engineers, Inc., 1981, pp. 405-415.

(Continued)

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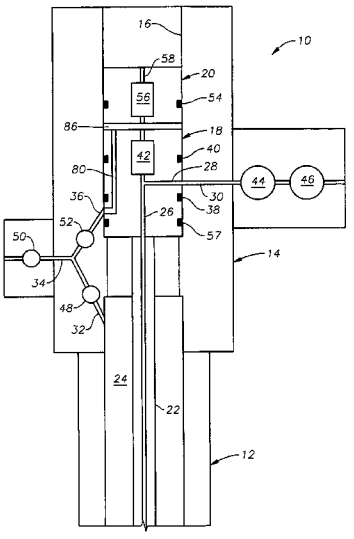
(57) **ABSTRACT**

A completion system for a subsea well includes a tree having a generally cylindrical wall forming an internal bore therethrough and a production port extending laterally through the wall in communication with the internal bore. The internal wall has a landing arranged to support a tubing hanger having seals for sealing the production port between the tubing hanger and the internal wall, the production port being arranged to communicate with a lateral production fluid outlet port in the tubing hanger. A workover port extends laterally from an opening in the internal wall below the production port and the production port seals and a tubing annulus seal sealing the workover port from the tubing annulus. A tubing annulus port extends from an opening in the tree below the tubing annulus seal and the tubing annulus port and workover port being arranged to be in fluid communication externally of the internal bore.

18 Claims, 10 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

6,062,314	A *	5/2000	Nobileau	166/368
6,227,300	B1 *	5/2001	Cunningham et al.	166/339
6,293,345	B1 *	9/2001	Watkins	166/368
6,302,212	B1 *	10/2001	Nobileau	166/368
6,360,822	B1 *	3/2002	Robertson	166/368
6,408,947	B1 *	6/2002	Cunningham et al.	166/339
6,453,944	B2 *	9/2002	Bartlett	137/601.01
6,470,968	B1 *	10/2002	Turner	166/348
6,755,254	B2 *	6/2004	DeBerry	166/368

FOREIGN PATENT DOCUMENTS

WO	WO 01/73254	10/2001
WO	WO 01/73256	10/2001
WO	WO 01/73259	10/2001
WO	WO 01/73260	10/2001

OTHER PUBLICATIONS

SPE 13976 D.S. Huber, G.F. Simmers and C.S. Johnson; *Through Bore Subsea Christmas Trees;* Sep. 1985; (p. 15).

Design Certification Manuals FOR Phillips North Hewett Subsea Completion Well 48/30-10; Jul. 29, 1986; (p. 3).

National Supply Company (UK) Limited; *Through Bore Tree System and Workover Riser 7 1/16" 5000 psi;* Jun. 1985; (pp. KD092771-KD092815).

National Supply Company (UK) Limited; *Through Bore Tree Syustem and Workover Riser 7 1/16"-5M*; Oct. 1985; (pp. KD092816-KD092837).

National Oilwell (UK) Limited; *Through Bore Tree System;* Jan. 1993; St. Magnus House; (p. 24).

The Nordic Council of Ministers Program for Petroleum Technology; *Electric Submersible Pump for Subsea Completed Wells;* Nov. 26-27, 1991; S. Sangesland; (p. 14).

Division of Petroleum Engineering and Applied Geophysics; NHT. Trondheim; Mar. 1990; *A Simplified Subsea System Design;* Sigbjorn Sangesland; (pp. 1-18).

Division of Petroleum Engineering and Applied Geophysics, NTH; *Simplified Subsea System Design;* Oct. 23-27 & Nov. 20-24, 1989; (pp. 1-31).

Welland Subsea Tree; Figure 8; (1 sheet) undated.

* cited by examiner

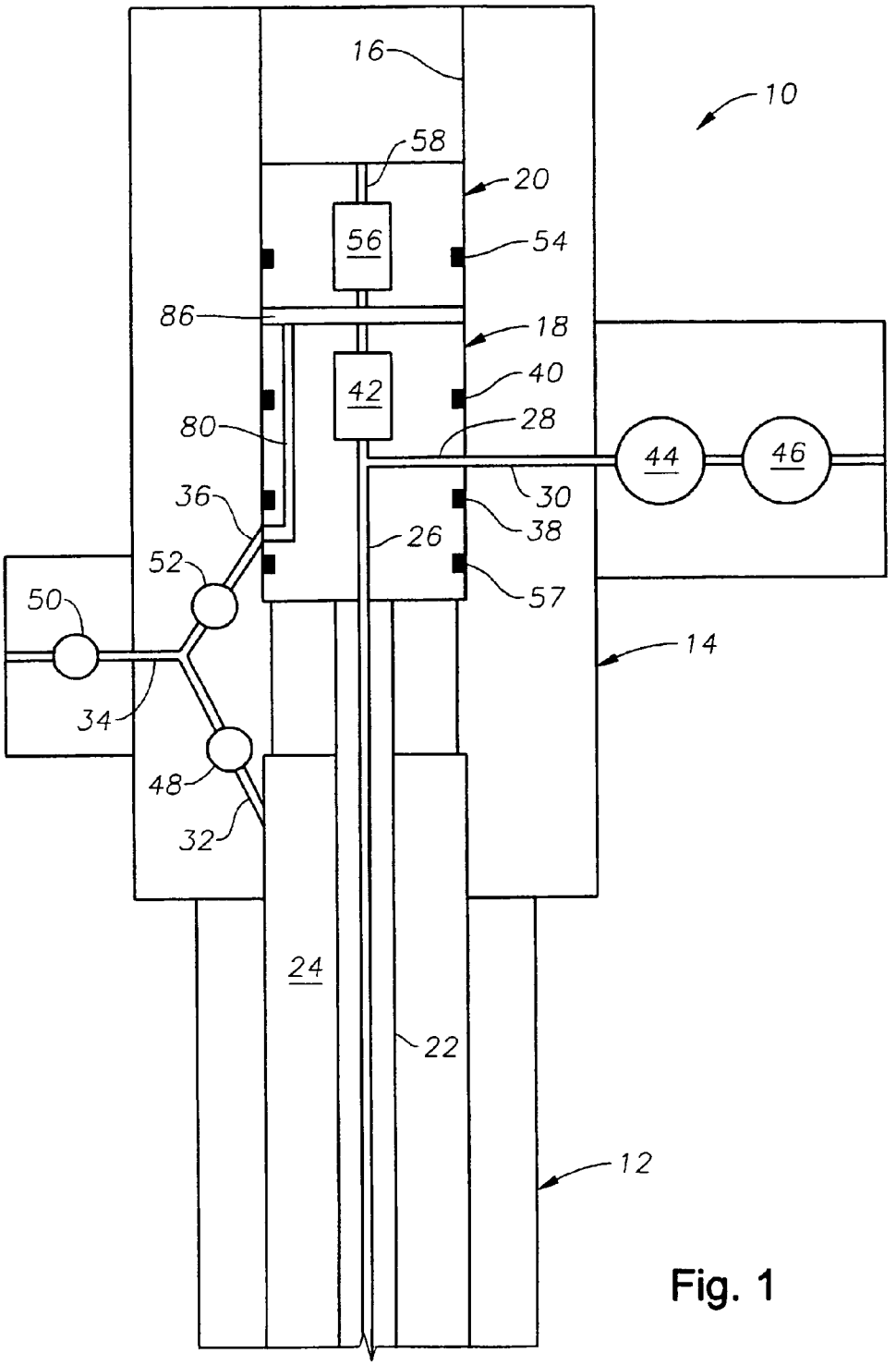

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Fig. 1

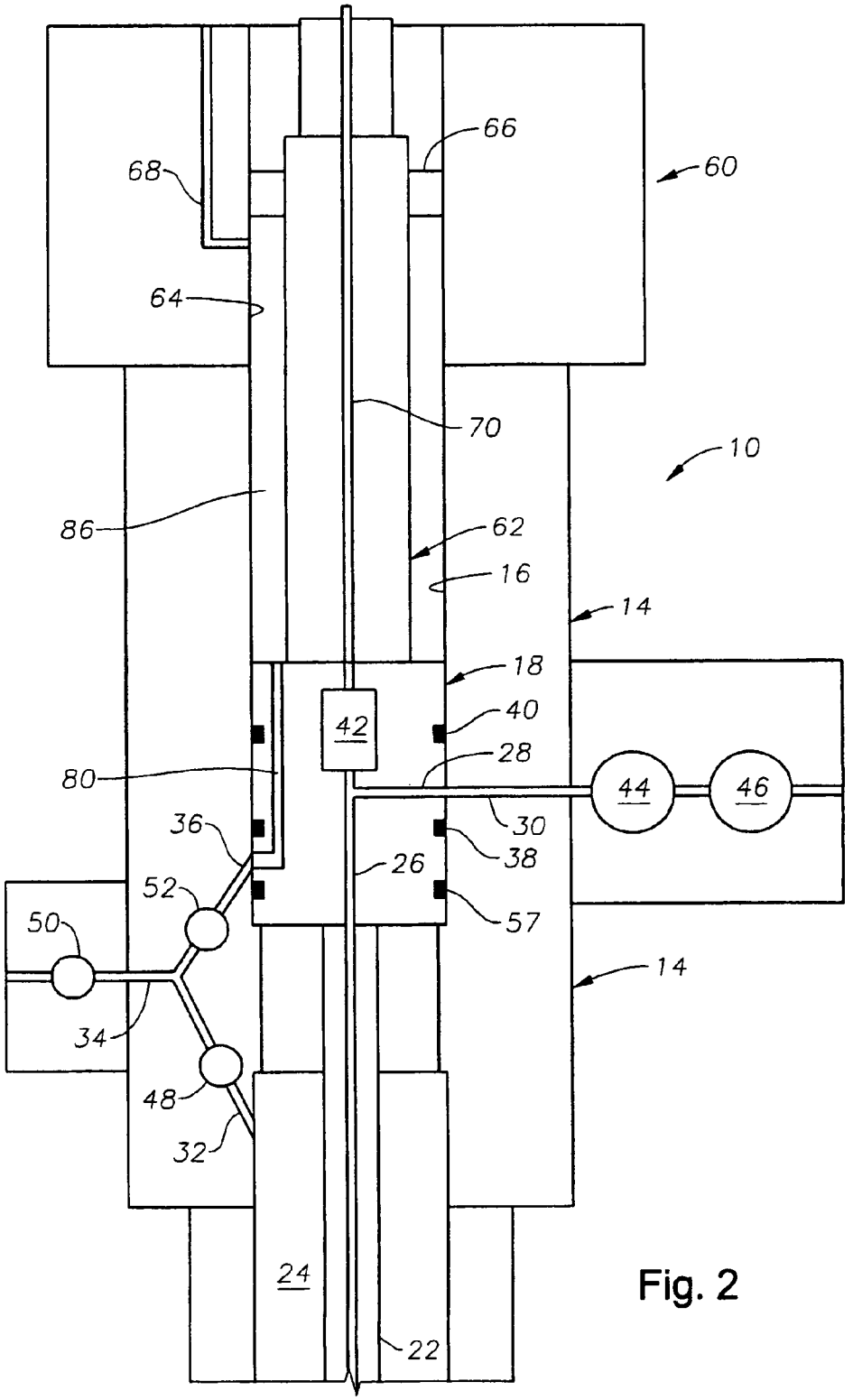
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Fig. 2

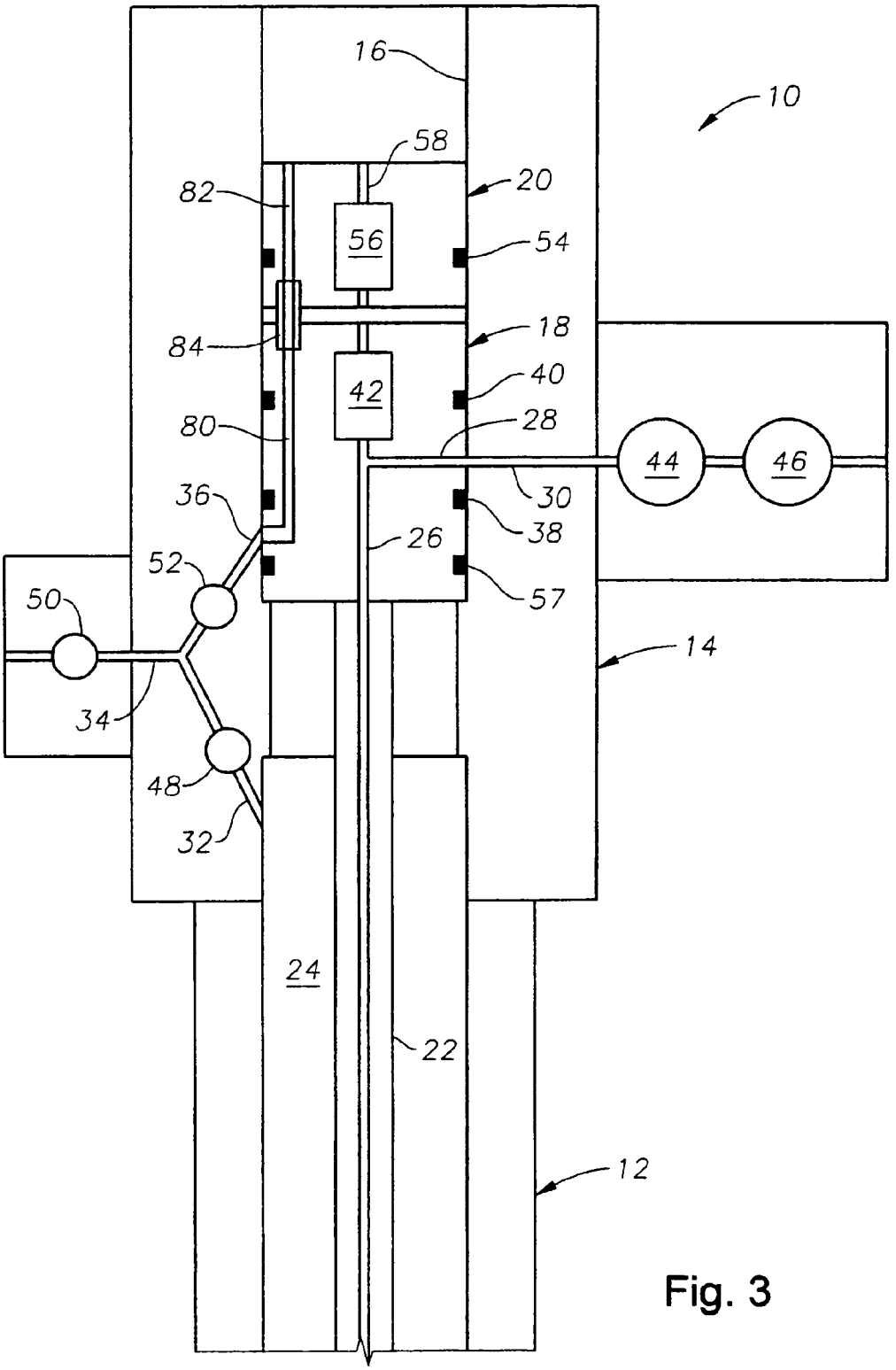
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Fig. 3

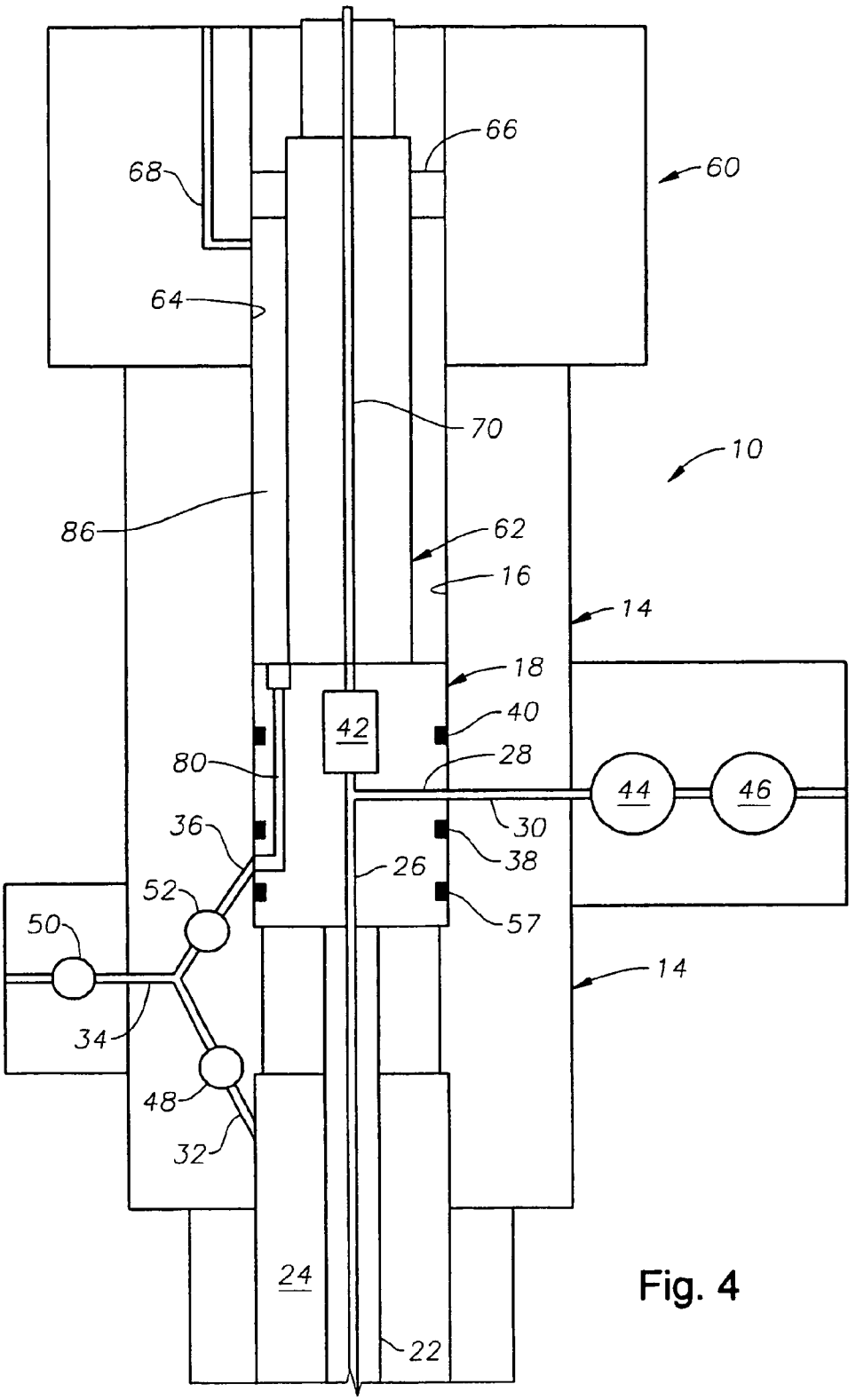
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Fig. 4

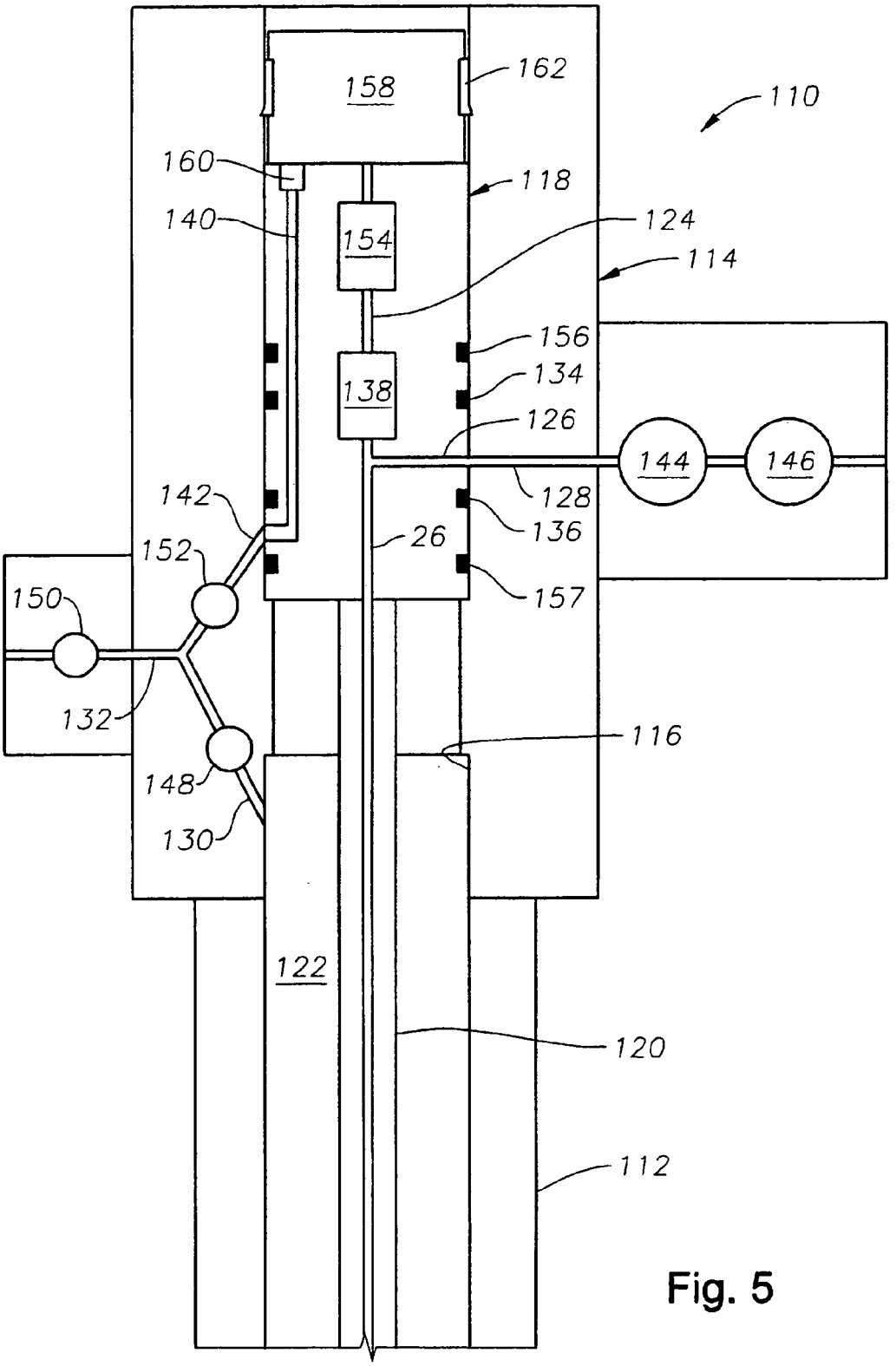
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Fig. 5

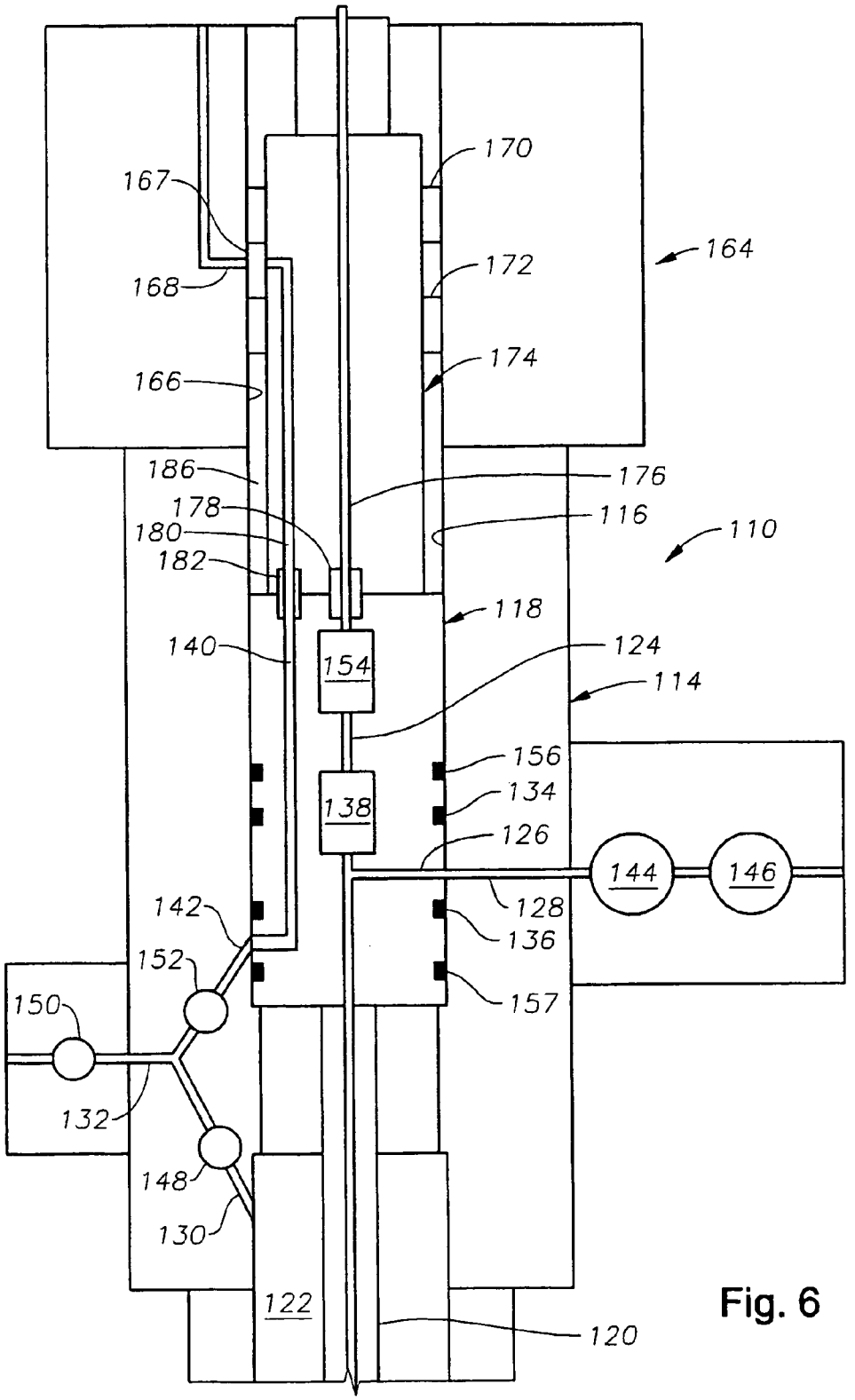
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Fig. 6

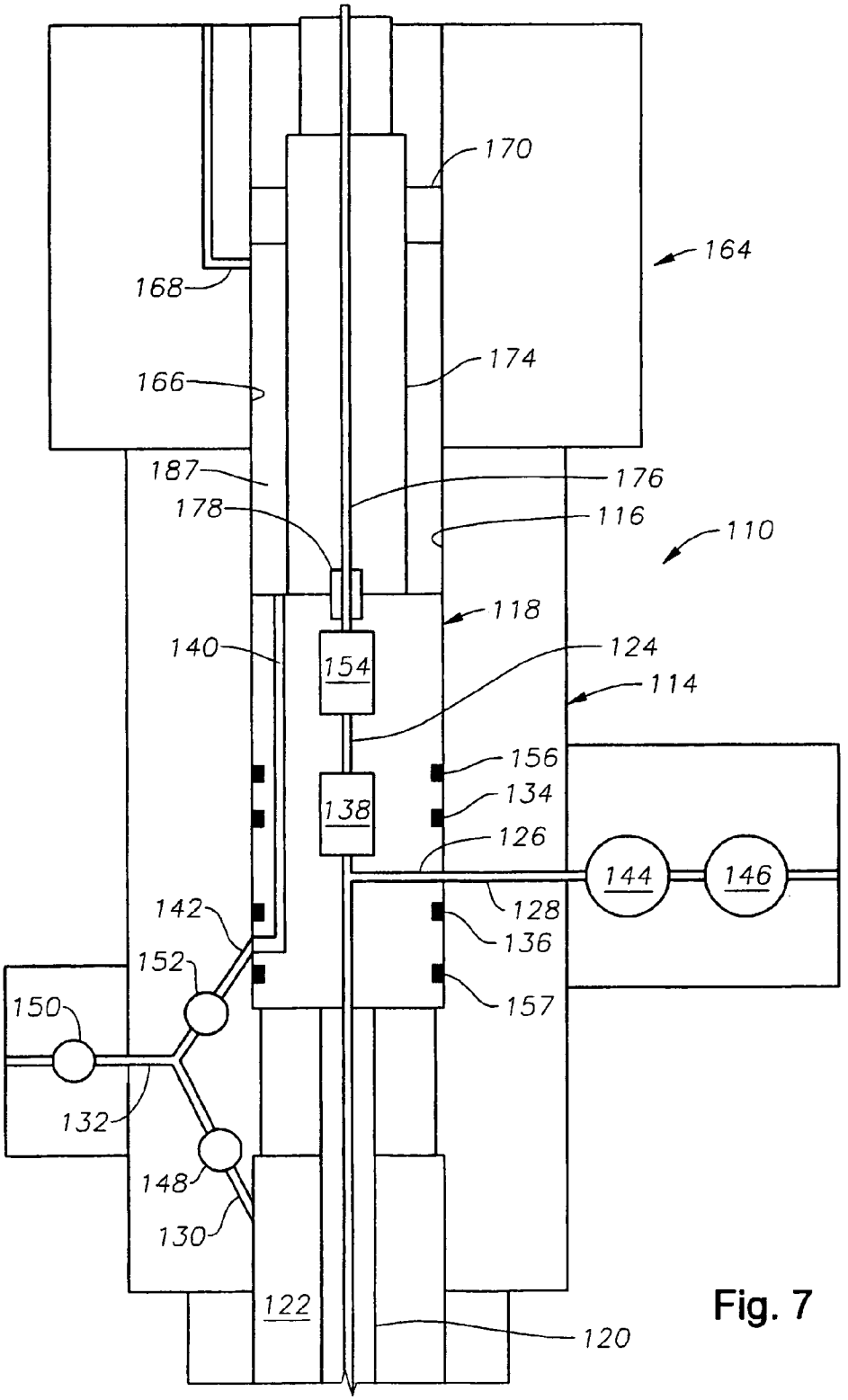
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Fig. 7

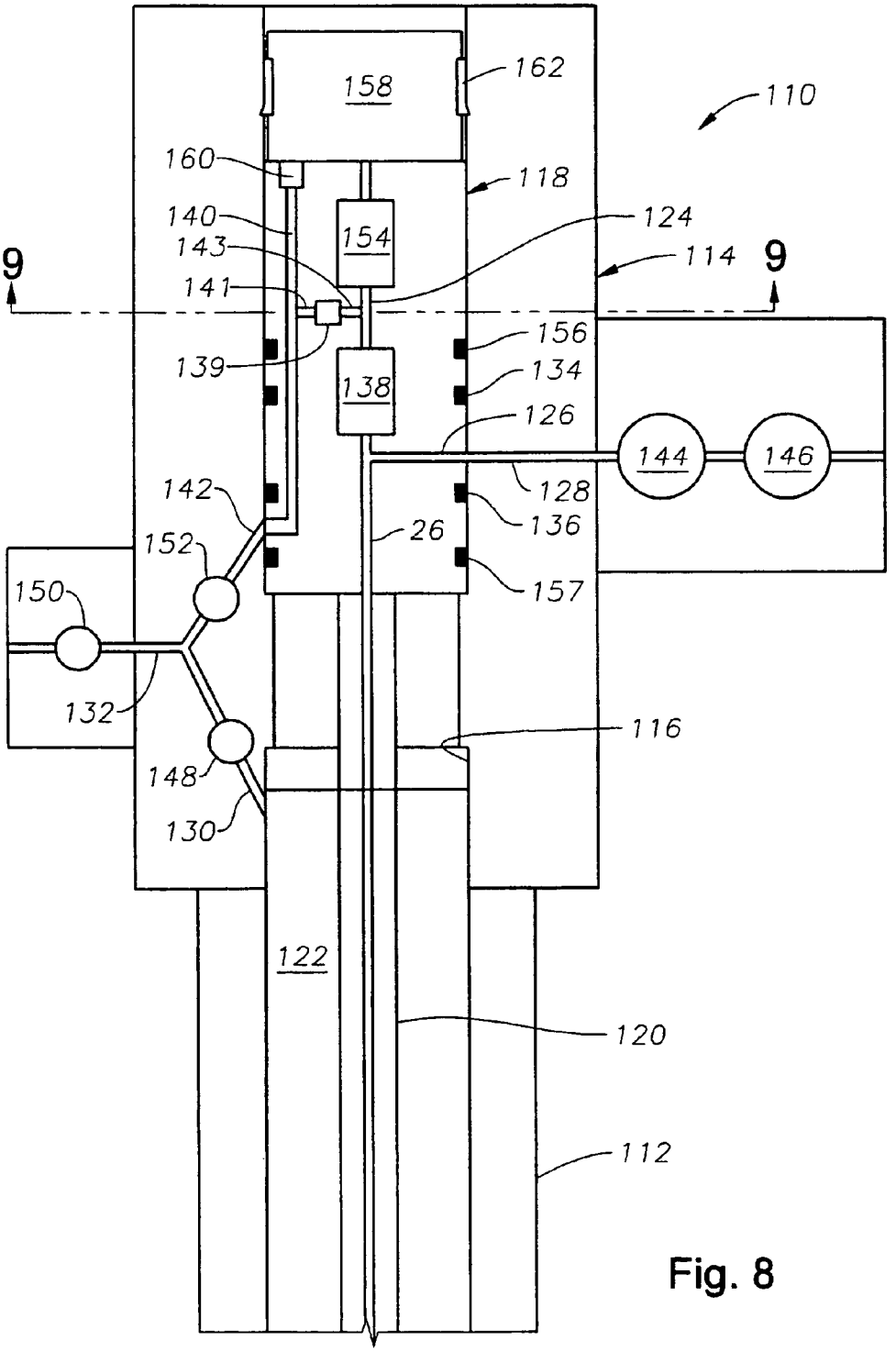
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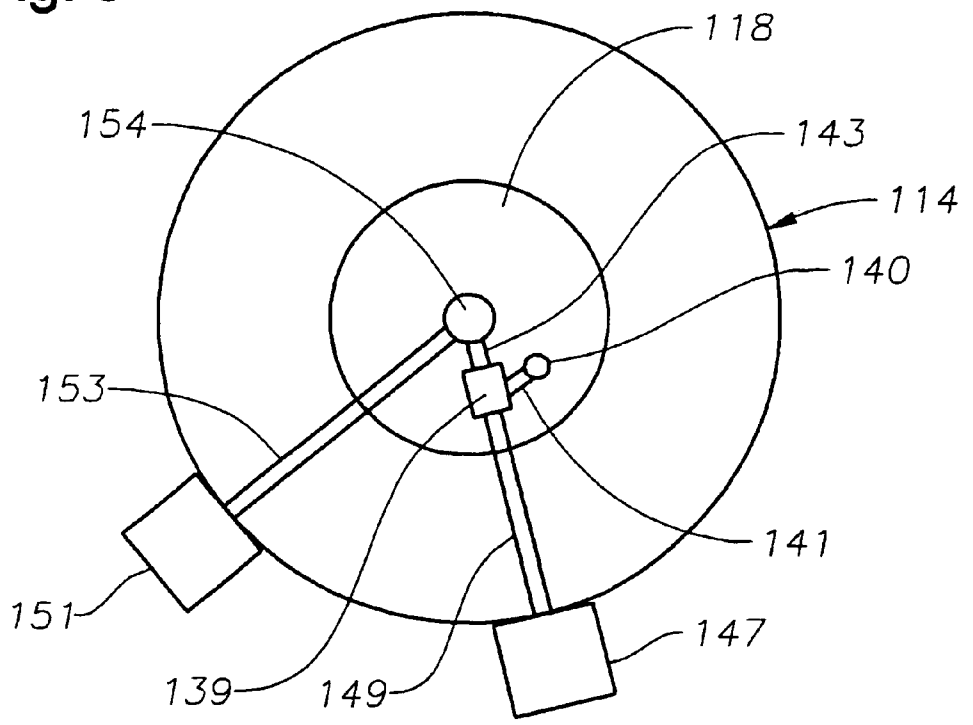
Fig. 8

Fig. 9



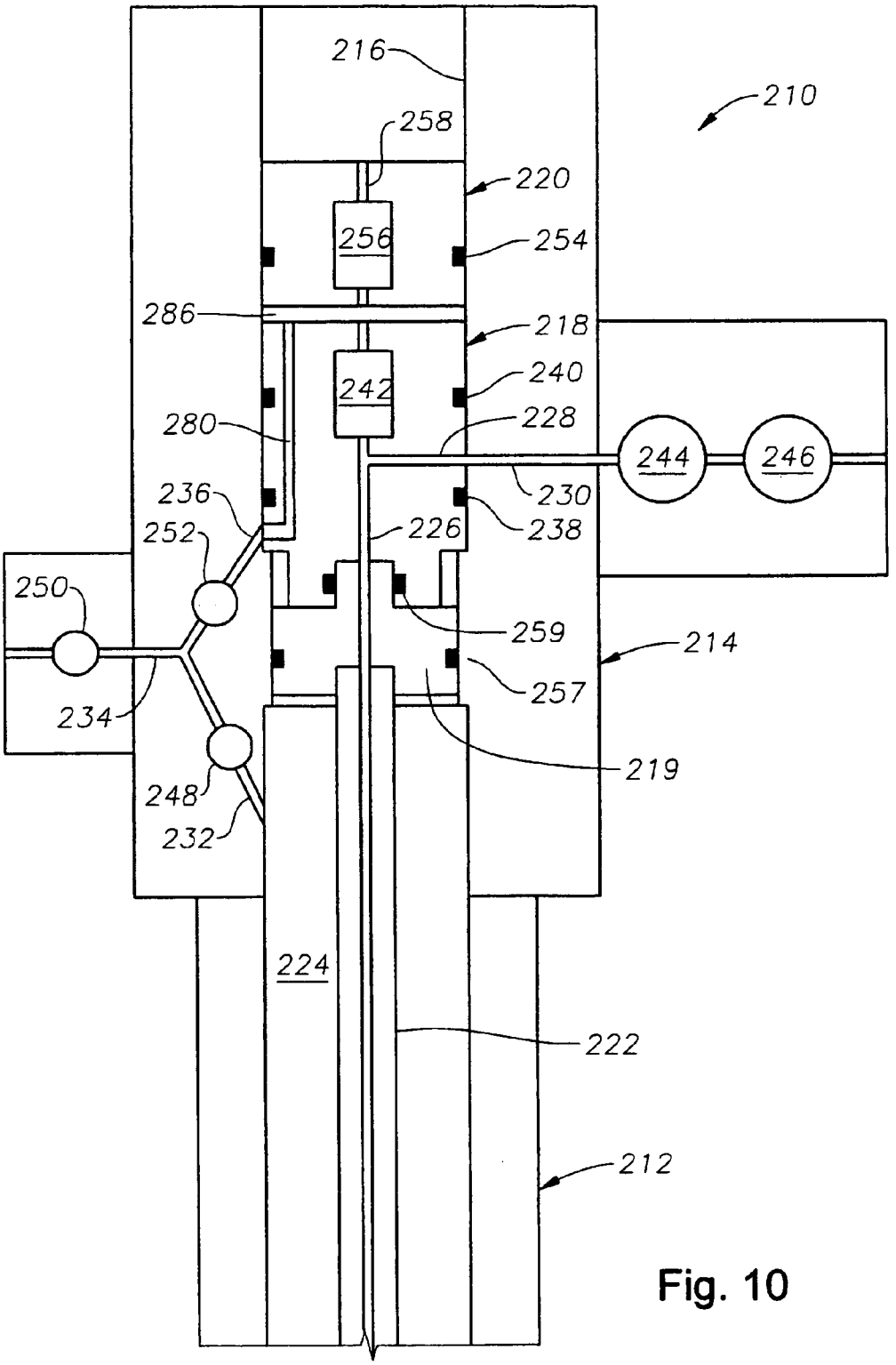

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Fig. 10

TUBING HANGER WITH ANNULUS BORE

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

BACKGROUND OF THE INVENTION

The present invention relates to a flow completion apparatus for producing oil or gas from a subsea well. More particularly, the invention relates to a flow completion apparatus which comprises a tubing hanger having an annulus bore which is adapted to communicate with a choke and kill line of a blowout preventer which is installed over the tubing hanger during installation and workover of the flow completion apparatus.

Flow completion assemblies for producing oil or gas from subsea wells may generally be categorized as either conventional or horizontal. A typical horizontal flow completion assembly is disclosed in U.S. Pat. No. 6,039,119, hereby incorporated herein by reference.

International Publication No. WO 01/73259 of International Application No. PCT/US01/09607 filed Mar. 22, 2001 and published Oct. 4, 2001, shows a tubing hanger with an annulus bore. International Publication No. WO 01/73259 is hereby incorporated herein by reference.

SUMMARY OF THE INVENTION

The flow completion apparatus comprises a wellhead housing which is installed at the upper end of the wellbore; a tubing spool which is connected over the wellhead housing and which includes a central bore which extends axially therethrough, a production outlet which communicates with the central bore, and an annulus passageway which communicates with the tubing annulus; a tubing hanger which is supported in the central bore and is connected to an upper end of the tubing string, the tubing hanger including a production bore which extends axially therethrough and a production passageway which communicates between the production bore and the production outlet; a first closure member which is positioned in the production bore above the production passageway; production seals positioned between the tubing hanger and central bore above and below the production passageway; and a tubing annulus seal which is positioned between the tubing hanger and the central bore below the production passageway and production seals. Furthermore, the tubing spool also comprises a workover passageway which extends between the annulus passageway and a portion of the central bore that is located between the production seals and the tubing annulus seal, and the tubing hanger also comprises an annulus bore which extends between the workover passageway and the upper end of the tubing hanger. In this manner, fluid communication between the tubing annulus and the upper end of the tubing hanger may be established through the annulus passageway, the workover passageway, and the annulus bore.

The flow completion apparatus further comprises a blowout preventer which is removably connectable to the top of the tubing spool and which includes a BOP bore, at least one set of BOP rams, and at least one choke and kill line that communicates with a portion of the BOP bore which is located below the BOP rams; and a tubing hanger running tool which is removably connectable to the top of the tubing hanger and which includes a generally cylindrical outer diameter surface

and a production port that communicates with the production bore in the tubing hanger. An annulus passageway extends between the annulus bore in the tubing hanger and the BOP choke and kill line. This passageway may either be the annular area around the tubing hanger running tool or may include an annulus port through the running tool that communicates between the annulus bore and an opening which is formed in the outer diameter surface of the tubing hanger running tool to communicate with the BOP choke and kill line. In this manner, fluid communication between the tubing annulus and the BOP choke and kill line may be established through the annulus passageway, the workover passageway, the annulus bore, either the annular area around the tubing hanger running tool or an annulus port in the tubing hanger running tool, and the portion of the BOP bore which is located below the closed BOP ram.

The annulus bore in the tubing hanger provides a convenient means for connecting the tubing annulus with the BOP choke and kill line. An annulus port in the tubing hanger running tool provides a closed path between the annulus bore in the tubing hanger and the BOP choke and kill line.

A first barrier between the wellbore and the environment is provided by both the first closure member in the production bore and the tubing annulus seal between the tubing hanger and the tubing spool. In addition, a second barrier between the wellbore and the environment is provided by both a second closure member that is positioned in the production bore above the first closure member and the production seals that are positioned between the tubing hanger and the tubing spool above the tubing annulus seal. In this manner, both the first and second barriers between the wellbore and the environment are mounted in or on the tubing hanger.

These and other objects and advantages of the present invention will be made apparent from the following detailed description, with reference to the accompanying drawings. In the drawings, the same reference numerals are used to denote similar components in the various embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a representation of one embodiment of the flow completion apparatus shown in the production mode of operation with the tubing hanger annulus bore extending between a first and second closure member;

FIG. **2** is a representation of the flow completion apparatus of FIG. **1** shown in the installation and workover mode of operation with an annulus passageway extending from the tubing hanger annulus bore to the choke and kill line;

FIG. **3** is a representation of another embodiment of the flow completion apparatus shown in the production mode of operation with an annulus bore extending from the workover passageway to that portion of the internal bore of the spool tree above the first and second closure members;

FIG. **4** is a representation of the flow completion apparatus of FIG. **3** shown in the installation workover mode of operation with an annulus passageway extending from the tubing hanger annulus bore to the choke and kill line;

FIG. **5** is a representation of a still another embodiment of the flow completion apparatus shown in the production mode of operation with an annulus bore extending to the top of the tubing hanger and sealed with a seal stab;

FIG. **6** is a representation of the flow completion apparatus of FIG. **5** shown in the installation and workover mode of operation with a passageway extending through the running tool between the tubing hanger annulus bore and the choke and kill line;

FIG. **7** is a representation of the flow completion apparatus of FIG. **5** shown in the installation and workover mode of operation with a passageway extending around the running tool between the tubing hanger annulus bore and the choke and kill line;

FIG. **8** is a representation of a further embodiment of the flow completion apparatus shown in the production mode of operation with an annulus bypass bore extending between the annulus bore and the production bore;

FIG. **9** is a cross section at plane **9-9** in FIG. **8**; and

FIG. **10** is a still further embodiment of the flow completion apparatus shown in the production mode of operation with a tubing suspension conduit below the tubing hanger.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention relates to methods and apparatus for flow completion and particularly for circulation in the borehole of a well during installation and workover. The present invention is susceptible to embodiments of different forms. There are shown in the drawings, and herein will be described in detail, specific embodiments of the present invention with the understanding that the present disclosure is to be considered an exemplification of the principles of the invention, and is not intended to limit the invention to that illustrated and described herein.

In particular, various embodiments of the present invention provide a number of different constructions and methods of operation of the completion system. The embodiments of the present invention also provide a plurality of methods for circulation in the borehole of a well. It is to be fully recognized that the different teachings of the embodiments discussed below may be employed separately or in any suitable combination to produce desired results. Reference to up or down will be made for purposes of description with up meaning away from the bottom of the well and down meaning toward the bottom of the well.

In the description which follows, the use of the same reference numerals throughout the specification and drawings indicates like parts. The drawing figures are not necessarily to scale. Certain features of the invention may be shown in exaggerated in scale or in somewhat schematic form and some details of conventional elements may not be shown in the interest of clarity and conciseness.

Referring initially to FIG. **1**, one embodiment of a flow completion apparatus according to the present invention, is generally indicated by reference numeral **10**. The flow completion apparatus **10** comprises a wellhead **12**, a tubing spool **14** which is connected and sealed to the wellhead and which includes a central bore **16** extending axially therethrough, a generally annular tubing hanger **18** which is supported on a shoulder located in the central bore, and a tree cap **20** which is installed in the central bore above the tubing hanger. The tubing hanger **18** is secured to the tubing spool **14** by a lockdown mechanism (not shown) and suspends a tubing string **22** that extends into the well bore and defines a tubing annulus **24** surrounding the tubing string. Tubing hanger **18** also includes a production bore **26** which communicates with the flowbore of the tubing string **22** and a lateral production passageway **28** which extends between the production bore **26** and the outer diameter of the tubing hanger. The tubing spool **14** includes a production outlet **30** which communicates with the production passageway **28**, an annulus passageway **32** which communicates with the tubing annulus **24**, and an annulus outlet **34** which is connected to the annulus passageway **32** and a workover passageway **36** which extends between the annulus passageway **32** and an area **86** of the central bore **16** above the tubing hanger **18**. In addition, the tubing hanger **18** is sealed to the tubing spool **14** by upper and lower, preferably metal, production seal rings **40**, **38**, each of which engages a corresponding annular sealing surface formed on the wall forming central bore **16**. The communication between the workover passageway **36** and the tubing annulus **24** is sealed by a tubing annulus seal ring **57**. Furthermore, the production bore **26** is sealed above the production passageway **28** by a suitable closure member **42**, such as a plug, which directs the flow of oil or gas from the tubing string **22** into the production passageway **30**.

The tubing hanger **18** also includes an annulus bore **80** which extends between the upper end and lower end of the tubing hanger **18**. In this manner, communication between the tubing annulus **24** and area **86** above the upper end of tubing hanger **18** is provided by the annulus passageway **32**, the workover passageway **36**, and the annulus bore **80**. This arrangement permits communication between the tubing annulus **24** and area **86** and also a choke and kill line in a BOP with tree cap **20** removed as shown in FIG. **2**.

The flow completion apparatus **10** may also comprise a production master valve **44** and a production wing valve **46** to control flow through the production outlet **30**, and an annulus master valve **48**, an annulus wing valve **50** and a workover valve **52** to control flow through the annulus passageway **32**, the annulus outlet **34** and the workover passageway **36**, respectively. While these valves may be any suitable closure members, they are preferably remotely operated gate valves. Moreover, some or all of the valves may be incorporated into the body of the tubing spool **14**, into separate valve blocks which are bolted onto the tubing spool, or into individual valve assemblies which are connected to their respective outlets or passageways in the tubing spool with separate lengths of conduit. Furthermore, the production outlet **30** and the annulus outlet **34** are preferably connected to respective flow loops which communicate with a surface vessel, either directly or via a manifold, in a manner that is well known in the art.

In the production mode of operation of the flow completion apparatus **10**, shown in FIG. **1**, a first barrier between the well bore and the environment is provided by the closure member **42** production seals **38**, **40**, and the tubing annulus seal **57**, which together serve to isolate the fluid in the wellbore from the environment above the tubing hanger. The second barrier is provided by the tree cap **20** and by a typically metal seal ring **54** which is disposed between the tree cap **20** and the tubing spool **14** and a wireline plug **56** which is positioned in an axial bore **58** extending through the tree cap. Thus, in the completion assembly **10**, the first barrier is associated with the tubing hanger **18** while the second barrier is associated with the tree cap **20**. Although not shown in FIG. **1**, the tree cap **20** also includes a lockdown mechanism to secure the tree cap to the tubing spool **14**.

Referring now to FIG. **2**, the flow completion assembly **10** is shown in the installation or workover mode of operation. In either of these modes of operation, a blowout preventer **60** is connected to the top of the tubing spool **14** and a tubing hanger running tool **62** is attached to the top of the tubing hanger **18**. The BOP includes an internal BOP bore **64**, at least one set of rams **66** which is capable of sealing against the tubing hanger running tool **62**, and at least one choke and kill line **68** for providing communication between the BOP bore below the rams **66** and a surface vessel (not shown). In addition, the tubing hanger running tool **62** comprises an internal bore **70**, or production port, which connects to the production bore **26** via a production stab (not shown). Also, although the

BOP rams are described herein as sealing against the tubing hanger running tool, it should be understood that the rams could instead seal against another member, such as an extension member or a work string, which comprises a production port that communicates with the production port of the tubing hanger running tool.

During both installation and workover of the flow completion assembly **10**, communication between the tubing annulus **24** and the surface vessel may be established through the annulus passageway **32**, the workover passageway **36**, the annulus bore **80**, the central bore **16**, the BOP bore **64**, and the choke and kill line **68**. For example, deep well circulation can be accomplished by pumping fluid down the tubing hanger running tool bore **70**, through the production bore **26**, through the flowbore of tubing string **22**, around or through the lower end of the tubing string **22**, up the tubing annulus **24**, through the annulus passageway **32**, through the workover passageway **36**, through the annulus bore **80**, into the central bore **16** above the tubing hanger **18**, into the BOP bore **64** and through the BOP choke and kill line **68** to the surface.

Referring now to FIGS. **3** and **4**, there is shown an alternative embodiment of the flow completion assembly **10** of FIGS. **1** and **2**. Annulus bore **80** may be made in flow communication with a secondary annulus bore **82** extending through tree cap **20** by including an annulus stab **84** that seals into the top of the annulus bore **80** and into the secondary annulus bore **82** in the bottom of tree cap **20**. This provides an annulus bore which extends from workover port **36** to that portion of the internal bore **16** of tubing spool **14** above both the first and second closure members, namely tree cap **20** and wire line plug **42**, respectively. Secondary annulus bore **82** may be closed and sealed by a seal stab (not shown) installed in the upper end of secondary annulus bore **82**

Referring now to FIG. **5**, another embodiment of a flow completion apparatus according to the present invention is generally indicated by reference numeral **110**. The flow completion apparatus comprises a wellhead **112**, tubing spool **114** which is mounted on the wellhead which includes a central bore **116** extending axially therethrough, and a generally annular tubing hanger **118** which is supported on a shoulder located in the central bore and from which is suspended a tubing string **120** that extends into the well bore and defines a tubing annulus **122** surrounding the tubing string. The tubing hanger **118** is secured to the tubing spool **114** by a lockdown mechanism (not shown) and includes a production bore **124** which communicates with the flowbore of the tubing string **120** and a lateral production passageway **126** which extends between the production bore **124** and the outer diameter of the tubing hanger. Similarly, the tubing spool **114** includes a production outlet **128** which communicates with the production passageway **126**, an annulus passageway **130** which communicates with the tubing annulus **122**, and an annulus outlet **132** which is connected to the annulus passageway. In addition, the tubing hanger **118** is sealed to the tubing spool **114** by an upper and lower, preferably metal, production seal rings **134**, **136**, each of which engages a corresponding annular sealing surface formed on the wall of central bore **116**. Furthermore, the production bore **124** is sealed above the production passageway **126** by a suitable closure member **138** which directs the flow of oil or gas from the tubing string **120** into the production passageway **126**. Ring seals **156**, **157**, located above and below production port **128** and production seals **134**, **136**, sealingly engage a corresponding annular sealing surface formed by the central bore **116**.

The tubing hanger **118** also includes an annulus bore **140** which extends between the top and the lower outer diameter of the tubing hanger **118**, and the tubing spool **114** comprises a workover passageway **142** that extends between the annulus passageway **130** and the annulus bore **140**. The communication between the workover passageway **142** and the tubing annulus **122** is sealed by tubing annulus seal ring **157**. In this manner, communication between the tubing annulus **122** and the top of tubing hanger **118** is provided by the annulus passageway **130**, the workover passageway **142**, and the annulus bore **140**. This arrangement permits communication between the tubing annulus **122** and a BOP to be routed through a tubing hanger running tool, shown in FIG. **6**, rather than in the area **186** of the central bore **116** above the tubing hanger **118**.

The flow completion apparatus **110** may also comprises a production master valve **144** and a production wing valve **146** to control flow through the production outlet **128**, and an annulus master valve **148**, an annulus wing valve **150** and a workover valve **152** to control flow through the annulus passageway **130**, the annulus outlet **132** and the workover passageway **142**, respectively. While these valves may be any suitable closure members, they are preferably remotely operated gate valves. Moreover, some or all of the valves may be incorporated into the body of the tubing spool **114**, into separate valve blocks which are bolted onto the tubing spool, or into individual valve assemblies which are connected to their respective outlets or passageways in the tubing spool with separate lengths of conduit. Furthermore, the production outlet **128** and the annulus outlet **132** are preferably connected to respective flow loops which communicate with a surface vessel, either directly or via a manifold, in a manner that is well known in the art.

In the production mode of operation of the flow completion apparatus **110**, shown in FIG. **5**, production seal **134** and tubing annulus seal **157** together function as a double barrier to isolate the fluid in the production passageway **126** from the environment below the tubing hanger **118** and production seal **134** and secondary seal **156** together function as a double barrier to isolate the fluid in the production passageway **126** from the environment above the tubing hanger **118**.

In accordance with the present invention, a first barrier between the well bore and the environment is provided by the closure member **138** and the production seals **134**, **136**, which together serve to isolate the fluid in the production bore from the environment above and below the tubing hanger **118**. A second barrier between the well bore and the environment is provided by a suitable second closure member **154**, which is mounted in the production bore **124** above the closure member **138**, and secondary seal **156** and tubing annulus seal **157**, preferably a metal ring seals, which are mounted on the tubing hanger **118** above and below production passageway **126**. Thus, the necessary first and second barriers for isolating the production passageway **126** from the environment are provided by components which are mounted on or in the tubing hanger **118**.

The present invention also provides for isolating the tubing annulus **122** from the environment above the tubing hanger **118** during the production mode of operation. Provided the annular master valve **148** and the workover valve **152** are closed, the production seals **134**, **136**, the secondary seal **156**, and the tubing annulus seal **157** will provide the required first and second barriers between the tubing annulus and the environment. However, when pressure in the tubing annulus **122** needs to be bled off through the annulus passageway **130** and the annulus outlet **132**, or when gas is introduced into the tubing annulus through the annulus outlet and the annulus passageway during gas lift applications, the annulus master valve **148** must be opened.

Therefore, the flow completion apparatus preferably also comprises a tree cap **158** which includes an annulus stab **160** that seals into the top of the annulus bore **140** to provide a second barrier, in conjunction with the workover valve **152**, between the tubing annulus **122** and the environment when the environment master valve **148** is open. While the tree cap **158** may include an annular, preferably non-metallic seal (not shown) to seal against the tubing spool **114** and thereby prevent sea water from entering the central bore **116**, the tree cap is not intended to provide a barrier against well pressure in the production bore. The tree cap **158** is preferably landed on the tubing hanger **118** and locked to the tubing spool **114** with a convention lockdown mechanism **162**. This lockdown mechanism will provide a backup to the lockdown mechanism used to secure the tubing hanger to the running tool. It should be noted that, although the tree cap **158** is depicted as an internal tree cap, it could instead be configured as an external tree cap.

Referring now to FIG. **6**, during installation and workover of the flow completion apparatus **110**, a BOP **164** is lowered on a riser (not shown) and connected and sealed to the top of the tubing spool **114**. The BOP **164** includes an internal BOP bore **166**, at least one choke and kill line **168**, and one or more sets of BOP rams **170**, **172**. In addition, a tubing hanger running tool **174** is connected to the top of the tubing hanger **118**. The tubing hanger running tool **174** is either connected to the tubing hanger at a surface vessel and used to lower the tubing hanger into the tubing spool during installation of the tubing hanger, or lowered through a riser and the BOP and connected to the tubing hanger in the tubing spool in anticipation of a workover operation. The tubing hanger running tool **174** is shown to comprise a generally cylindrical outer diameter surface, a production port **176** which is connected to a production bore **124** in the tubing hanger **118** by a suitable production seal stab **178**, and an annulus port **180** which extends from a portion of the outer diameter surface of tubing hanger running tool **174** to a suitable annulus seal stab **182** that engages the tubing hanger annulus bore **140**.

Thus, with the BOP rams **170**, **172** sealed against the tubing hanger running tool **174**, communication between the tubing annulus **122** and the BOP choke and kill line **168** may be established through the annulus passageway **130**, the workover passageway **142**, the annulus bore **140**, the annulus port **180**, and the portion **167** of the BOP bore **166** which is located between the BOP rams **170**, **172**. For example, with the annulus wing valve **150** closed, pressure can be transmitted from the surface vessel down the choke and kill line **168**, through the annulus portion **180**, through the tubing hanger annulus bore **140**, through the workover passageway **142**, through the annulus passageway **130**, and into the tubing annulus **122**. The well circulation may be accomplished by closing both the annulus wing valve **150** and the production master valve **144** and pumping fluid down the choke and kill line **168** through the annulus port **180**, through the annulus bore **140**, through the workover passageway **142**, through the annulus passageway **130**, down the tubing annulus **122**, past the downhole packer, up the tubing string **120**, through the production bore **124**, and up the production port **176**. Moreover, since the flow between the tubing hanger annulus bore **140** and the choke and kill line **168** is restricted by the tubing hanger running tool **174**, no possibility exists that the flow will foul the tubing hanger lockdown mechanism or erode the central bore **116**.

Referring now to FIG. **7**, there is shown an alternative embodiment of the flow completion assembly **110** of FIG. **6**. Annulus bore **140** communicates with the choke and kill line **168** through an annular passageway **187** between the tubing hanger running tool **174** and the internal bores of the BOP **166** and the tubing spool **114**.

Referring now to FIG. **8**, an alternate embodiment of a flow completion apparatus according to the present invention as described in FIG. **5**, is generally indicated by reference numeral **110**. The flow completion apparatus comprises a wellhead **112**, tubing spool **114** which is mounted on the wellhead which includes a central bore **116** extending axially therethrough, and a generally annular tubing hanger **118** which is supported on a shoulder located in the central bore and from which is suspended a tubing string **120** that extends into the well bore and defines a tubing annulus **122** surrounding the tubing string. The tubing hanger **118** is secured to the tubing spool **114** by a lockdown mechanism (not shown) and includes a production bore **124** which communicates with the flowbore of the tubing string **120** and a lateral production passageway **126** which extends between the production bore and the outer diameter of the tubing hanger. Similarly, the tubing spool **114** includes a production outlet **128** which communicates with the production passageway **126**, an annulus passageway **130** which communicates with the tubing annulus **122**, and an annulus outlet **132** which is connected to the annulus passageway. In addition, the tubing hanger **118** is sealed to the tubing spool **114** by an upper and lower, preferably metal, production seal rings **134**, **136**, each of which engages a corresponding annular sealing surface formed by the wall of the central bore **116**. Furthermore, the production bore **124** is sealed above the production passageway **126** by a suitable closure member **138** which directs the flow of oil or gas from the tubing string **120** into the production passageway **126**. Ring seals **156**, **157**, located above and below production port **128** and production seals **134**, **136**, sealingly engage a corresponding annular sealing surface formed by the wall of the central bore **116**.

The tubing hanger **118** also includes an annulus bore **140** which extends between the top and the outer diameter of the tubing hanger **118**, and the tubing spool **114** comprises a workover passageway **142** that extends between the annulus passageway **130** and the annulus bore **140**. The communication between the workover passageway **142** and the tubing annulus **122** is sealed by an annular seal ring **157**. Tubing hanger **118** also includes an annulus bypass bore **141** extending from annulus bore **140** through valve **139** and continuing through bypass bore **143** to production bore **124**. In this manner fluid communication between the tubing annulus **122** and the production bore **124** above closure member **138** is provided.

Referring now to FIG. **9**, a section view of FIG. **8** generally indicated a valve actuation member **147** and valve stem **149** for valve **139**. Valve actuation as indicated here is described in U.S. Pat. No. 5,992,527 which is hereby incorporated herein by reference.

Similar valve actuation member **151** and valve stem **153** are shown as an alternate for valve closure member **154**. The valve actuation member **151** attached to tubing spool **114** may be used outside or inside the necessary second barriers for isolating the production bore **124** from the environment as described earlier.

The flow completion apparatus **110** may also comprise a production master valve **144** and a production wing valve **146** to control flow through the production outlet **128**, and an annulus master valve **148**, an annulus wing valve **150** and a workover valve **152** to control flow through the annulus passageway **130**, the annulus outlet **132** and the workover passageway **142**, respectively. While these valves may be any suitable closure members, they are preferably remotely oper-

ated gate valves. Moreover, some or all of the valves may be incorporated into the body of the tubing spool **114**, into separate valve blocks which are bolted onto the tubing spool, or into individual valve assemblies which are connected to their respective outlets or passageways in the tubing spool with separate lengths of conduit. Furthermore, the production outlet **128** and the annulus outlet **132** are preferably connected to respective flow loops which communicate with a surface vessel, either directly or via a manifold, in a manner that is well known in the art.

In the production mode of operation of the flow completion apparatus **110**, shown in FIG. **8**, production seal **136** and tubing annulus seal **157** together function as a double barrier to isolate the fluid in the production passageway **126** from the environment below the tubing hanger **118** and production seal **134** and secondary seal **156** together function as a double barrier to isolate the fluid in the production passageway **126** from the environment above the tubing hanger **118**.

In accordance with the present invention, a first barrier between the well bore and the environment is provided by the closure member **138** and the production seals **134**, **136**, which together serve to isolate the fluid in the production bore from the environment above and below the tubing hanger **118**. A second barrier between the well bore and the environment is provided by a suitable second closure member **154**, which is mounted in the production bore **124** above the closure member **138**, and secondary seal **156** and tubing annulus seal **157**, preferably a metal ring seals, which are mounted on the tubing hanger **118** above and below production passageway **126**. Thus, the necessary first and second barriers for isolating the production passageway **126** from the environment are provided by components which are mounted on or in the tubing hanger **118**.

The present invention also provides for isolating the tubing annulus **122** from the environment above the tubing hanger **118** during the production mode of operation. Provided the annular master valve **148** and the workover valve **152** are closed, the production seals **134**, **136**, the secondary seal **156**, and the tubing annulus seal **157** will provide the required first and second barriers between the tubing annulus and the environment. However, when pressure in the tubing annulus **122** needs to be bled off through the annulus passageway **130** and the annulus outlet **132**, or when gas is introduced into the tubing annulus through the annulus outlet and the annulus passageway during gas lift applications, the annulus master valve **148** must be opened.

Therefore, the flow completion apparatus preferably also comprises a tree cap **158** which includes an annulus stab **160** that seals into the top of the annulus bore **140** to provide a second barrier, in conjunction with the workover valve **152**, between the tubing annulus **122** and the environment when the environment master valve **148** is open. While the tree cap **158** may include an annular, preferably non-metallic seal (not shown) to seal against the tubing spool **114** and thereby prevent sea water from entering the central bore **116**, the tree cap is not intended to provide a barrier against well pressure in the production bore. The tree cap **158** is preferably landed on the tubing hanger **118** and locked to the tubing spool **114** with a convention lockdown mechanism **162**. This lockdown mechanism will provide a backup to the lockdown mechanism used to secure the tubing hanger to the running tool. It should be noted that, although the tree cap **158** is depicted as an internal tree cap, it could instead be configured as an external tree cap.

Referring now to FIG. **10**, one embodiment of a flow completion apparatus according to the present invention, is generally indicated by reference numeral **210**. The flow completion apparatus **210** comprises a wellhead **212**, a tubing spool **214** which is connected and sealed to the wellhead and which includes a central bore **216** extending axially therethrough, a generally annular tubing hanger **218** which is supported on a shoulder located in the central bore, and a tree cap **220** which is installed in the central bore above the tubing hanger. The tubing hanger **218** is secured to the tubing spool **214** by a lockdown mechanism (not shown) and is in communication with a tubing string **222** that extends into the well bore and defines a tubing annulus **224** surrounding the tubing string. Tubing hanger **218** also includes a production bore **226** which communicates with the flowbore of the tubing string **222** and a lateral production passageway **228** which extends between the production bore and the outer diameter of the tubing hanger. The tubing spool **214** includes a production outlet **230** which communicates with the production passageway **228**, an annulus passageway **232** which communicates with the tubing annulus **224**, and an annulus outlet **234** which is connected to the annulus passageway **232** and a workover passageway **236** which extends between the annulus passageway **232** and an area **286** of the central bore **216** above the tubing hanger **218**. In addition, the tubing hanger **218** is sealed to the tubing spool **214** by a lower, preferably metal production seal ring **238** and an upper, preferably metal production seal ring **240**, each of which engages a corresponding annular sealing surface formed by the wall of the central bore **216**. The communication between the workover passageway **236** and the tubing annulus **224** is sealed by tubing annulus seal ring **257** and by seal ring **259** in sealing relationship with tubing suspension conduit **219**. Furthermore, the production bore **226** is sealed above the production passageway **228** by a suitable closure member **242**, such as a plug, which directs the flow of oil or gas from the tubing string **222** into the production passageway **230**.

In a similar manner as described for FIG. **1**, the tubing hanger **218** also includes an annulus bore **280** which extends between the upper end and lower end of the tubing hanger **218**. In this manner, communication between the tubing annulus **224** and the upper end of tubing hanger **218** is provided by the annulus passageway **32**, the workover passageway **36**, and the annulus bore **280**. This arrangement permits communication between tubing annulus **224** and area **286** and also a choke and kill line in a BOP with tree cap **220** removed.

The flow completion apparatus **210** may also comprise a production master valve **244** and a production wing valve **246** to control flow through the production outlet **230**, and an annulus master valve **248**, an annulus wing valve **250** and a workover valve **252** to control flow through the annulus passageway **232**, the annulus outlet **234** and the workover passageway **236**, respectively. While these valves may be any suitable closure members, they are preferably remotely operated gate valves. Moreover, some or all of the valves may be incorporated into the body of the tubing spool **214**, into separate valve blocks which are bolted onto the tubing spool, or into individual valve assemblies which are connected to their respective outlets or passageways in the tubing spool with separate lengths of conduit. Furthermore, the production outlet **230** and the annulus outlet **234** are preferably connected to respective flow loops which communicate with a surface vessel, either directly or via a manifold, in a manner that is well known in the art. See U.S. Pat. No. 5,372,199, hereby incorporated herein by reference.

In the production mode of operation of the flow completion apparatus **210**, shown in FIG. **10**, a first barrier between the well bore and the environment is provided by the closure member **242** production seals **238**, **240**, and the tubing annulus seal **257**, which together serve to isolate the fluid in the

wellbore from the environment above the tubing hanger. The second barrier is provided by the tree cap **220** and by a typically metal seal ring **254** which is disposed between the tree cap **220** and the tubing spool **214** and a wireline plug **256** which is positioned in an axial bore **258** extending through the tree cap. Thus, in the completion assembly **210**, the first barrier is associated with the tubing hanger **218** while the second barrier is associated with the tree cap **220**. This embodiment allows the removal of tubing hanger **218** while leaving tubing string and tubing suspension conduit **219** in tubing spool **214**.

The embodiments described above assume a requirement for double barriers. It should be appreciated that one of the barriers may be eliminated should only one barrier be required in a particular jurisdiction.

It should be recognized that, while the present invention has been described in relation to the preferred embodiments thereof, those skilled in the art may develop a wide variation of structural and operational details without departing from the principals of the invention. For example, the various elements shown in the different embodiments may be combined in a manner not illustrated above. Therefore, the appended claims are to be construed to cover all equivalents falling within the true scope and spirit of the invention.

What is claimed is:

1. An assembly for a subsea well, the assembly comprising:

a tree body having a generally cylindrical wall forming an internal bore therethrough and a production outlet extending laterally through said wall in communication with said internal bore;

said internal wall having a landing arranged to support a tubing hanger, the tubing hanger having first seals sealing the production outlet between the tubing hanger and said internal wall, said production outlet arranged to communicate with a lateral production passageway in the tubing hanger;

a workover port extending laterally from a workover port opening in said internal wall;

said workover port opening being located below said first seals;

said tubing hanger having a second seal below said workover port opening sealing between the tubing hanger and said internal wall;

a tubing annulus passageway extending from an opening in said tree body below said second seal; and

said tubing annulus passageway and workover port being arranged to be in fluid communication externally of said internal bore.

2. The assembly of claim **1** wherein said tubing hanger includes a annulus bore in communication with said workover port.

3. The assembly of claim **2** wherein said annulus bore communicates with an area above said tubing hanger.

4. The assembly of claim **2** further including a flow passageway extending from said annulus bore to a choke or kill line.

5. The assembly of claim **4** further including a circulation path extending through said tubing hanger, tubing, tubing annulus, tubing annulus passageway, workover passageway, annulus bore, flow passageway and choke or kill line.

6. The assembly of claim **2** further including a tool having an annulus outlet in communication with said annulus bore.

7. The assembly of claim **6** wherein said annulus outlet communicates with a choke or kill line.

8. The assembly of claim **2** further including a closure member sealing said internal bore above said tubing hanger.

9. The assembly of claim **8** wherein said closure member includes a flow passageway therethrough communicating with said annulus bore.

10. A flow completion apparatus for controlling the flow of fluid through a tubing string which extends into a well bore and defines a tubing annulus surrounding the tubing string, the flow completion apparatus comprising:

a wellhead housing which is installed at the upper end of the well bore;

a tubing spool which is connected over the wellhead housing and which includes a central bore that extends axially therethrough, a production outlet which communicates with the central bore, and an annulus passageway which communicates with the tubing annulus;

a tubing hanger which is supported in the central bore, is connected to an upper end of the tubing string, and includes a production bore which extends axially therethrough and a production passageway which communicates between the production bore and the production outlet;

a first closure member which is positioned in the production bore above the production passageway;

a seal which is positioned between the tubing hanger and the central bore below the production passageway;

a workover passageway in the tubing spool which extends between the annulus passageway and a portion of the central bore that is located below the seal;

an annulus bore in the tubing hanger which extends between the workover passageway and the upper end of the tubing hanger; and

a fluid passageway extending between the tubing annulus and the upper end of the tubing hanger being established through the annulus passageway, the workover passageway and the annulus bore.

11. An assembly for a subsea well, the assembly comprising:

a tree body having a generally cylindrical wall forming an internal bore therethrough and a production outlet extending laterally through said wall in communication with said internal bore;

said internal wall having a landing arranged to support a tubing hanger having a production bore therethrough, the tubing hanger having first seals sealing the production outlet between the tubing hanger and said internal wall, said production outlet arranged to communicate with said production bore through a lateral production passageway in the tubing hanger;

a workover port extending laterally from a workover port opening in said internal wall;

said workover port opening being located below said first seals;

said tubing hanger having a second seal below said workover port opening sealing between the tubing hanger and said internal wall and said tubing hanger having an annulus bore in communication with said workover port opening;

a tubing annulus passageway extending from an opening in said tree body below said second seal;

said tubing annulus port and workover port being arranged to be in fluid communication externally of said internal bore; and

a bypass passageway in said tubing hanger communicating said annulus bore with said production bore.

12. The assembly of claim **11** further including a flow control member controlling flow through said bypass passageway.

13. The assembly of claim 12 wherein said flow control member includes an actuator extending through said tubing hanger and tree.

14. An assembly for a subsea well, the assembly comprising:

a tree body having a generally cylindrical wall forming an internal bore therethrough and a production outlet extending laterally through said wall in communication with said internal bore;

said internal wall having a landing arranged to support a tubing hanger;

a production member disposed in said internal bore on said tubing hanger and having first seals sealing the production outlet between the production member and said internal wall, said production outlet arranged to communicate with a lateral production passageway in said production member;

a workover port extending laterally from a workover port opening in said internal wall;

said workover port opening being located below said first seals;

said tubing hanger having a second seal below said workover port opening sealing between the tubing hanger and said internal wall;

a tubing annulus passageway extending from an opening in said tree body below said second seal; and

said tubing annulus port and workover port being arranged to be in fluid communication externally of said internal bore.

15. An assembly for a subsea well, the assembly comprising:

a tree body having a generally cylindrical wall forming an internal bore therethrough and a production outlet extending laterally through said wall in communication with said internal bore;

said internal wall having a landing arranged to support a tubing hanger, said tubing hanger having a first seal sealing between said tubing hanger and said internal wall above said production outlet and a second seal sealing between said tubing hanger and said internal wall below said production outlet, said production outlet arranged to communicate with a lateral production passageway in said tubing hanger;

a workover port extending laterally from a workover port opening in said internal wall;

said workover port opening being located below said first seal;

said tubing hanger having a third seal below said workover port opening sealing between said tubing hanger and said internal wall;

a tubing annulus passageway extending from an opening in said tree body below said third seal; and

said tubing annulus passageway and workover port being arranged to be in fluid communication externally of said internal bore.

16. A well production assembly located at an upper end of a string of tubing extending into a well and including a blowout preventer with a choke or kill line, comprising:

a production tree having a longitudinal axis, an axial bore and a lateral production passage, the lateral production passage having an inlet at the bore and extending laterally through a sidewall of the production tree;

a tubing hanger landed in the axial bore and adapted to be located at an upper end of a string of tubing, the tubing hanger having a vertical production passage extending axially through the tubing hanger and a lateral production passageway which extends laterally from the vertical production passage through the tubing hanger and has an outlet at the exterior of the tubing hanger which registers with the inlet of the lateral production passage of the production tree;

a member closing the tubing hanger vertical production bore from the production tree axial bore, the member, tubing hanger, production tree, and blowout preventer forming an area therebetween; and

the tubing hanger having an annulus passage extending through the tubing hanger offset from the vertical production passage, the annulus passage having a lower end adapted to be in flow communication with a tubing annulus surrounding the string of tubing and an upper end extending through the tubing hanger in flow communication with the area.

17. The well production assembly of claim 16 wherein the area is in flow communication with the choke or kill line.

18. A well production assembly located at an upper end of a string of tubing extending into a well, comprising:

a production tree having a longitudinal axis, an axial bore and a lateral production passage, the lateral production passage having an inlet at the bore and extending laterally through a sidewall of the production tree;

a tubing hanger landed in the axial bore and adapted to be located at an upper end of a string of tubing, the tubing hanger having a vertical production passage extending axially through the tubing hanger and a lateral production passageway which extends laterally from the vertical production passage through the tubing hanger and has an outlet at the exterior of the tubing hanger which registers with the inlet of the lateral production passage of the production tree;

a first closure member closing the tubing hanger vertical production bore from the production tree axial bore;

a second closure member installed in the production tree axial bore above the tubing hanger, the second closure member, tubing hanger, and production tree forming an area therebetween; and

the tubing hanger having an annulus passage extending through the tubing hanger offset from the vertical production passage, the annulus passage having a lower end adapted to be in flow communication with a tubing annulus surrounding the string of tubing and an upper end extending through the tubing hanger in flow communication with the area.

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