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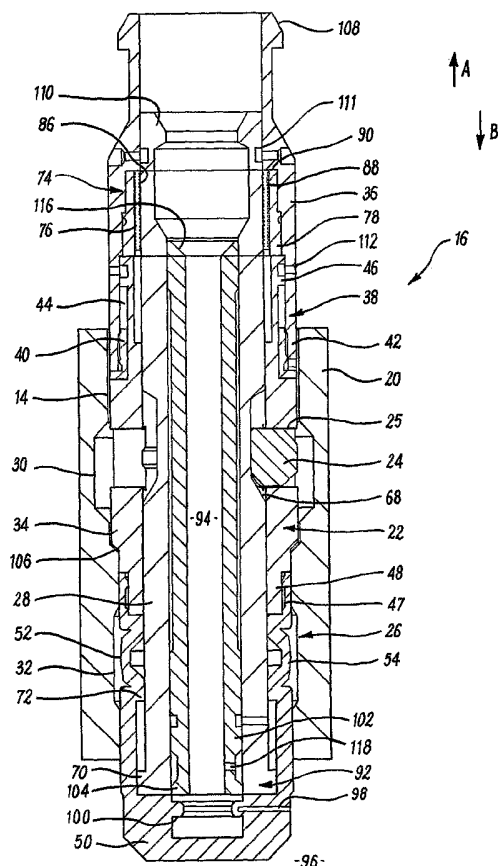
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(54) Title: TREE PLUG



(57) Abstract: The invention relates to a tree plug for a tree of the type used in the oil and gas exploration and production industry. The invention also relates to a plug and to a lock adapted to be located in various types of downhole tubing, and to a method of plugging a tree bore. In one embodiment, a tree plug (16,17) for a tree (10) having a main tree bore (14) is disclosed, the tree plug having a plug body (22), a number of locking members (24) mounted for radial movement relative to the plug body between retracted and extended positions, a radially expandable seal element (26), and a mandrel (28). The mandrel is translated relative to the plug body to urge the locking members to the extended position, and to exert an axial force on the seal element to radially expand the seal element, to thereby lock and seal the plug within the tree bore.



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1 **TREE PLUG**

2
3 The present invention relates to a tree plug and to a
4 method of plugging a tree bore. In particular, but not
5 exclusively, the present invention relates to a tree plug
6 for a tree of the type used in the oil and gas
7 exploration and production industry. The present
8 invention also relates to a plug and a lock adapted to be
9 located in various types of downhole tubing.

10
11 In the oil and gas exploration and production industry,
12 well fluids are recovered from a well through a Christmas
13 tree located on a wellhead of the well, which controls
14 flow of the well fluids. In offshore environments, these
15 Christmas trees are located on the seabed, and a number
16 of trees on different wells may be coupled to a subsea
17 pumping station and thus to a rig or other production
18 facility, enabling access to a number of wells from a
19 single rig. Christmas trees of this type are typically
20 referred to as horizontal subsea trees, and have an
21 outlet extending from a side of the tree.

22
23 In use during production of well fluids through a
24 horizontal tree, tree plugs or crown plugs are generally
25 installed in a main bore of the tree in pairs to close an

1 upper end of the bore, and well fluids are recovered
2 through the side outlet, controlled by appropriate
3 valves. Conventional tree plugs typically comprise some
4 form of locking member for locking the plug relative to
5 the tree and an arrangement of seals, which abut an inner
6 seal surface of the tree bore and thus seal the bore when
7 the plug is set. When it is desired to carry out an
8 intervention procedure, the crown plugs are removed to
9 allow access to the wellbore through the tree.

10
11 To prevent damage to the seal surface of the tree bore,
12 for example, by passage of tools or rotation of a drill
13 string within the bore, a thin sleeve is located in the
14 tree bore. This both narrows the bore diameter and must
15 be removed before a plug can be set.

16
17 In a similar fashion, it is often necessary to locate a
18 tubing or tool string within existing borehole casing or
19 liner, for example, to carry out completion or workover
20 activities. US Patent No. 5,865,255 (assigned to
21 Halliburton Energy Services, Inc.) discloses a nipple and
22 associated lock mandrel for locating tubing strings in
23 subterranean wells. The nipple is coupled to a tubing
24 string for transport and positioning within the well and
25 includes an internal bore at least as great as a 'drift'
26 diameter of a tubing string to which it is attached. A
27 latch profile is formed in a tubular body of the nipple
28 and a seal bore is formed above the profile, the diameter
29 of the seal bore being greater than the diameter of the
30 main parts of the body internal bore. In this fashion,
31 the seal bore is protected from direct exposure to axial
32 fluid flow through the internal bore. A lock mandrel is
33 configured for use with the nipple and includes a

1 radially outwardly extendable circumferential seal and a
2 number of keys which are radially slidingly received in
3 an opening of an outer housing of the lock mandrel, to
4 engage a latch profile in the nipple.
5

6 In use, an expander sleeve of the lock mandrel is
7 displaced axially downwardly to urge the seal radially
8 outwardly and to prevent the keys from disengaging the
9 latch profile in the nipple. However, the lock mandrel of
10 US 5,865,255 requires the keys to be radially outwardly
11 biased in order to successfully engage the latch profile.
12 During running of the lock mandrel into the tubing, the
13 keys contact the internal surface of the tubing with a
14 likelihood of damage to one or both of the keys and the
15 tubing, and in particular to the seal bore of the nipple.
16

17 Furthermore, as the expander sleeve of the lock mandrel
18 is urged downwardly to set the seal and hold the keys
19 radially outwardly in engagement with the latch profile,
20 forces exerted on the lock mandrel by fluid flow through
21 the tubing string will tend to cause the expander sleeve
22 to move axially upwardly, thereby releasing the lock.
23

24 Another lock is disclosed in European Patent Publication
25 No. 0298683 (Petrolin Wireline Services Limited). EP
26 0298683 discloses a downhole lock assembly having a lock
27 mandrel with a number of keys or dogs which are urged
28 outwardly to set the tool. The lock mandrel is set on a
29 no-go shoulder in downhole tubing and by jarring down to
30 shear setting pins, fingers on an inner mandrel are
31 allowed to retract so that the inner mandrel may move
32 upwardly to expand the lock-out keys.
33

1 However, the downhole lock of EP 0298683 has a relatively
2 complex mechanism for setting the dogs which requires
3 precise alignment of finger ends of the inner mandrel
4 with grooves in an outer body in order that the lock is
5 correctly set. Furthermore, the lock mandrel is not
6 sealed to the respective tubing.

7
8 It is amongst the objects of embodiments of the present
9 invention to obviate or mitigate at least one of the
10 foregoing disadvantages.

11
12 According to a first aspect of the present invention,
13 there is provided a tree plug for a tree having a main
14 tree bore, the tree plug comprising:
15 a plug body;
16 at least one locking member mounted for radial movement
17 relative to the plug body between retracted and extended
18 positions;
19 at least one radially expandable seal element; and
20 a mandrel adapted to be translated relative to the plug
21 body to urge the locking member to the extended position
22 and to exert an axial force on the seal element to
23 radially expand the seal element, to thereby lock and
24 seal the plug within the tree bore.

25
26 The invention therefore provides a tree plug including a
27 movable mandrel which may serve both for urging the
28 locking member to the extended position, and for exerting
29 an axial force on the seal element. In this fashion, the
30 mandrel may cause the tree plug to be both locked and
31 sealed within the tree bore. This is facilitated, in
32 part, by the provision of a seal element which is
33 radially expandable by exertion of an axial force, such

1 as a compressive load, on the seal element. It will be
2 understood that this load may be exerted on the seal
3 element by the mandrel during movement of the mandrel
4 relative to the plug body.

5
6 The mandrel may be axially movable within the plug body,
7 and it will be understood that references herein to the
8 mandrel being axially movable are relative to a
9 longitudinal axis of the plug body.

10
11 Preferably the mandrel is upwardly movable relative to
12 the plug body for urging the locking member to the
13 extended position and for exerting the axial force on the
14 seal element. It will be understood that reference herein
15 to the term 'upward' are in a vertical sense, but that
16 where the tree bore is deviated or disposed at an angle
17 from the vertical, the term upward will be understood to
18 mean in a direction along the tree bore towards the
19 surface and thus may be from a downstream to an upstream
20 location relative to a direction of flow of well fluids
21 through the tree to surface.

22
23 The plug may comprise a pressure equalisation assembly
24 for selectively equalising pressure between an interior
25 and an exterior of the plug. By facilitating pressure
26 equalisation across the plug, the plug may be safely
27 removed by ensuring that a large differential pressure
28 does not exist between the interior and exterior of the
29 plug.

30
31 The pressure equalisation assembly may comprise a
32 pressure equalisation passage, channel or the like for
33 facilitating pressure equalisation. The passage may be

1 normally or initially closed and may be adapted to be
2 selectively opened for pressure equalisation.

3

4 The equalisation assembly may comprise a pressure
5 equalisation mandrel, tube, body or the like mounted for
6 movement with respect to the plug body for equalising
7 pressure between the plug interior and exterior. The
8 pressure equalisation mandrel may be adapted to
9 selectively open the passage on movement of the mandrel
10 with respect to the plug body. In embodiments of the
11 invention, the passage may be formed in the plug body and
12 an internal end of the passage may be closed by an
13 internal wall of the plug body, or by a shoulder, boss,
14 nub, valve, cap or the like. The pressure equalisation
15 mandrel may be adapted to shear, cut or abrade the
16 internal wall or the like on movement of the mandrel with
17 respect to the plug body, to open the passage, and may
18 include an appropriate cutting surface or element.

19

20 The pressure equalisation mandrel may be dimensioned and
21 located within the main mandrel such that when it is
22 desired to release the plug, the pressure equalisation
23 mandrel is moved to equalise pressure between the
24 interior and exterior of the plug before the main mandrel
25 is moved to release the locking member and the seal
26 element. This may ensure that pressure between the
27 interior and exterior of the plug is equalised prior to
28 release of the plug from the tree bore.

29

30 The plug may comprise a locking mechanism for restraining
31 the mandrel, and thus for restraining the locking member
32 in the extended position and the seal element in the
33 radially expanded position. The locking mechanism may be

1 adapted to permit movement of the mandrel in a first
2 axial direction with respect to the plug body and to
3 restrain movement of the mandrel in a second, opposite
4 axial direction. In this fashion, movement of the mandrel
5 with respect to the plug body in a first direction (to
6 set the locking member and the seal) may be permitted
7 and, following such movement, the locking mechanism may
8 restrain the mandrel against return movement, to thereby
9 restrain the locking member and the seal element in the
10 respective extended and expanded positions. The locking
11 mechanism may comprise a lock or latch ring, which is
12 preferably a one-piece ring, but may be comprised of a
13 plurality of segments or the like, the lock or latch ring
14 serving for restraining movement of the mandrel relative
15 to the plug body. The lock ring may be provided between
16 the mandrel and the plug body, and may comprise a
17 plurality of locking teeth or protrusions, such as
18 ratchet teeth, which may be adapted to engage
19 corresponding teeth on the mandrel. It will be understood
20 that interengagement of the respective lock ring and
21 mandrel ratchet teeth may serve for restraining the
22 mandrel against movement. The ratchet teeth of the lock
23 ring and the mandrel may be shaped to permit movement of
24 the mandrel with respect to the plug body in said first
25 direction and to restrain the mandrel against movement in
26 said second direction.

27

28 The lock or latch ring may form an inner ring and the
29 locking mechanism may also comprise an outer lock or
30 latch ring, preferably comprising a plurality of locking
31 segments, but alternatively comprising a one-piece ring.
32 The outer locking segments may be adapted to be located
33 between the inner lock ring and the plug body. The inner

1 and outer lock rings may be adapted to co-operate to
2 selectively restrain the mandrel against movement with
3 respect to the plug body. For example, the segments may
4 define a thread, a plurality of ratchet teeth or other
5 protrusions for engaging a corresponding thread on an
6 outer surface of the inner lock ring. Interengagement
7 between the outer locking threads and the threads on the
8 inner lock ring, and between the inner lock ring ratchet
9 teeth and the mandrel ratchet teeth may serve for
10 together restraining the mandrel against movement with
11 respect to the plug body. This may be achieved by
12 selectively restraining the outer lock ring against axial
13 movement with respect to the plug body.

14
15 The outer lock ring may be selectively radially moveable
16 in order to permit movement of the mandrel with respect
17 to the plug body; radial movement of the outer ring may
18 cause disengagement of the outer and inner ring threads,
19 thereby facilitating movement of the mandrel, which may
20 carry the inner lock ring during its movement. The outer
21 ring, in particular, the segments may be resilient or
22 sprung and may at least initially be held in a stressed
23 configuration until such time as the segments are
24 permitted to radially move relative to the mandrel. When
25 such radial movement of the segments is permitted, the
26 segments may spring outwardly to release the inner lock
27 ring and allow movement of the mandrel.

28
29 The plug body may comprise a main plug body portion and a
30 second portion or sub coupled to the main plug body
31 portion and selectively moveable with respect thereto.
32 The sub may define an internal recess or area for
33 receiving the outer lock ring segments, to facilitate

1 radial movement of the segments and thus release the
2 mandrel when the sub is moved axially relative to the
3 main plug body portion to align the segments with the
4 recess. In this fashion, the segments can be arranged to
5 move radially to release the mandrel by translating the
6 sub relative to the main plug body portion.

7
8 Preferably the seal element is a generally annular
9 element and may be substantially ring-shaped. The seal
10 element is preferably also adapted to be axially
11 compressed and thus shortened in length when an axial
12 force is exerted on the seal element by the mandrel, thus
13 urging the seal element outwardly into sealing contact
14 with the tree bore. Further preferably, the seal element
15 is adapted to increase in radial width when an axial
16 force is exerted thereon by the mandrel.

17
18 The seal element may be provided as an integral part of
19 the plug body, or as a separate component adapted to be
20 coupled to or mounted on the plug body.

21
22 The seal element may have a wall of a reduced
23 (undeformed) wall thickness in a region of the seal
24 element wall to be deformed into sealing contact with the
25 tree bore, relative to a remainder of the seal element.
26 Accordingly, the seal element may be influenced to deform
27 radially outwardly in a desired location. For example, an
28 axially central region of the seal element may be of a
29 wall thickness which is reduced relative to regions of
30 the seal element spaced in first and/or second axial
31 directions away from said central region.

32

1 The seal element may define a zone of deformation where
2 the element is adapted to be urged into sealing contact
3 with the tree bore.

4
5 The seal element may be adapted to provide a seal between
6 a first and a second surface which may be between an
7 internal surface of the tree bore and an external surface
8 of the plug, and the element may comprise: an inner
9 deformable surface, an outer deformable surface, the
10 inner and outer surfaces being joined at opposed first
11 and second ends providing a body defining an interior
12 volume entirely bounded by the said surfaces and said
13 ends, a deformable filler material within said interior
14 volume, wherein the element deforms in a predetermined
15 manner to seal between the first and second surfaces when
16 said ends are brought toward each other. The seal element
17 may therefore comprise a seal element as defined in the
18 applicant's International Patent Application No.
19 PCT/GB2004/003631 (WO2005/022012).

20
21 Preferably, the locking member and the seal element are
22 adapted to engage corresponding lock and seal recesses
23 provided in the tree bore and which may be provided in a
24 wall of a tubing forming the tree bore. By providing a
25 seal recess in which the seal element is received, it is
26 not necessary to provide a protective sleeve in the tree
27 bore and, furthermore, recessing the seal surface reduces
28 or avoids fluid flow damage to the seal surface, in use.

29
30 Preferably, the plug comprises a plurality of locking
31 members, which may comprise locking dogs, keys or the
32 like located in radially extending recesses or apertures
33 in the plug body. The locking member may comprise a cam

1 surface or ramp adapted to co-operate with a
2 corresponding surface on the mandrel, such that the
3 mandrel may urge the locking member radially outwardly on
4 translation of the mandrel relative to the plug body.
5

6 According to a second aspect of the present invention,
7 there is provided a tree comprising:

8 a main tree bore and a tree plug located in the tree bore
9 and sealed relative to the bore, the tree plug comprising
10 a plug body; at least one locking member mounted for
11 radial movement relative to the plug body between
12 retracted and extended positions; at least one radially
13 extendable seal element; and a mandrel adapted to be
14 translated relative to the plug body to urge the locking
15 member to the extended position to engage a latch recess
16 in the tree bore and to exert an axial force on the seal
17 element to radially expand the seal element to engage a
18 seal recess in the tree bore, to thereby lock and seal
19 the plug within the tree.
20

21 According to a third aspect of the present invention,
22 there is provided a downhole plug adapted to be located
23 in downhole tubing, the plug comprising:

24 a plug body;
25 at least one locking member mounted for radial movement
26 relative to the plug body between retracted and extended
27 positions;
28 at least one radially expandable seal element; and
29 a mandrel adapted to be translated relative to the plug
30 body to urge the locking member to the extended position
31 and to exert an axial force on the seal element to
32 radially expand the seal element, to thereby lock and
33 seal the plug within the downhole tubing.

1
2 According to a fourth aspect of the present invention,
3 there is provided a downhole lock adapted to be located
4 in downhole tubing, the downhole lock comprising:
5 a main body;
6 at least one locking member mounted for radial movement
7 relative to the main body between retracted and extended
8 positions;
9 at least one radially expandable seal element; and
10 a mandrel adapted to be translated relative to the main
11 body to urge the locking member to the extended position
12 and to exert an axial force on the seal element to
13 radially expand the seal element, to thereby lock and
14 seal the downhole lock within the downhole tubing.

15
16 It will be understood that the principles and features of
17 the tree plug defined in the first aspect of the present
18 invention may be provided in a downhole plug or lock for
19 alternative uses, such as for locating a tubing or tool
20 string within a casing or liner.

21
22 According to a fifth aspect of the present invention
23 there is provided a method of plugging a tree bore
24 comprising the steps of:
25 locating a tree plug within the tree bore;
26 translating a mandrel of the tree plug relative to a body
27 of the plug, to urge a locking member mounted for radial
28 movement relative to the plug body from a retracted to an
29 extended position to cause the locking member to engage a
30 latch recess in the tree bore, and to exert an axial
31 force on a seal element of the plug to radially expand
32 the seal element into sealing abutment with a seal recess

1 in the tree bore, to thereby lock and seal the plug
2 within the tree.

3
4 According to a sixth aspect of the present invention,
5 there is provided a tree plug for a tree having a main
6 tree bore, the tree plug comprising:
7 a plug body;
8 at least one locking member mounted for radial movement
9 relative to the plug body between retracted and extended
10 positions;
11 at least one radially expandable seal element; and
12 a mandrel adapted to be translated upwardly relative to
13 the plug body to urge the locking member to the extended
14 position and to radially expand the seal element, to
15 thereby lock and seal the plug within the tree bore.

16
17 According to a seventh aspect of the present invention,
18 there is provided a tree plug for a tree having a main
19 tree bore, the tree plug comprising:
20 a plug body;
21 at least one locking member mounted for radial movement
22 relative to the plug body between retracted and extended
23 positions;
24 at least one radially expandable seal element;
25 a mandrel adapted to be translated relative to the plug
26 body to urge the locking member to the extended position
27 and to radially expand the seal element, to thereby lock
28 and seal the plug within the tree bore; and
29 a locking mechanism comprising an inner lock ring having
30 a set of inner protrusions for engaging corresponding
31 outer protrusions on the mandrel, and an outer lock ring
32 having a set of inner protrusions for engaging
33 corresponding outer protrusions on the inner lock ring,

1 interaction between the outer lock ring protrusions, the
2 inner lock ring protrusions and the mandrel protrusions
3 permitting movement of the mandrel in a first direction
4 relative to the plug body and restraining the mandrel
5 against movement in a second, opposite direction to
6 thereby restrain the locking member in the extended
7 position and the seal element in a radially expanded
8 position;

9 wherein the outer lock ring is selectively radially
10 outwardly moveable to disengage the outer lock ring
11 protrusions and the outer protrusions on the inner lock
12 ring, to permit movement of the mandrel in said second
13 direction to release the plug.

14
15 It will be understood that the features of the tree plug
16 of the sixth and seventh aspects of the present invention
17 may equally be provided in a downhole plug or lock, in a
18 similar fashion to the tree plug defined in the first
19 aspect of the invention.

20
21 Also, further features of the invention of the second,
22 third, fourth, sixth and seventh aspects are defined in
23 relation to the first aspect of the invention.

24
25 Embodiments of the invention will now be described, by
26 way of example only, with reference to the accompanying
27 drawings, in which:

28
29 Fig. 1 is a schematic, partial cross-sectional view of a
30 subsea horizontal Christmas tree with two tree plugs
31 located within the tree, in accordance with a preferred
32 embodiment of the present invention;

33

1 Fig. 2 is a detailed, longitudinal cross-sectional view
2 of one of the tree plugs shown in Fig. 1;

3
4 Fig. 3 is an enlarged perspective view of part of the
5 tree plug of Fig. 2 with a sub of a body of the plug
6 removed, for clarity;

7
8 Figs. 4 and 5 are longitudinal half-sectional views of a
9 seal element forming part of a tree plug in accordance
10 with an alternative embodiment of the present invention,
11 shown both prior to and subsequent to expansion;

12
13 Figs. 6 and 7 are longitudinal half-sectional views of
14 seal elements forming parts of a tree plug in accordance
15 with a further alternative embodiment of the present
16 invention, again shown prior to and subsequent to
17 expansion;

18
19 Fig. 8 is an enlarged perspective view of an inner lock
20 ring forming part of a locking mechanism of the tree plug
21 of Fig. 2;

22
23 Fig. 9 is an enlarged, perspective view of an outer lock
24 ring forming part of the locking mechanism;

25
26 Figs. 10 and 11 are views of the tree plug of Fig. 2 at
27 later stages of a process of running, setting, releasing
28 and retrieving the plug; and

29
30 Fig. 12 is a longitudinal, half-sectional view of a tree
31 plug in accordance with a further alternative embodiment
32 of the present invention.

33

Turning firstly to Fig. 1, there is shown a subsea horizontal Christmas tree, the Christmas tree indicated generally by reference numeral 10. The Christmas tree 10 is located on a wellhead 12 of an oil or gas well and serves, amongst other things, for controlling flow of well fluids. The Christmas tree 10 includes a main bore 14 and, when it is desired to provide a secure barrier in the tree 10 to close an upper end of the bore 14, lower and upper tree plugs 16, 17 are located within the bore 14, enabling production from the well to be directed through a side outlet 2 having valves 6, 8 for controlling fluid flow therethrough.

Fig. 2 is a longitudinal cross-sectional view of the lower tree plug 16, which is in accordance with a preferred embodiment of the present invention. It will be understood that the upper plug 17 is of similar structure and that the description of the plug 16 applies equally to the plug 17. The plug 16 is shown in Fig. 2 in a running position, and has been run into the tree 10 through tubing extending to a production rig (not shown) at the sea surface. This tubing has been coupled to the tree 10 for running-in the plug 16, and is not normally required to obtain production fluids from the well.

Part of a housing 20 of the tree 10 is shown in Fig. 2 and defines a portion of the tree main bore 14. The tree plug 16 comprises a plug body 22, and at least one locking member in the form of a locking dog or key 24, which is mounted for radial movement relative to the plug body 22 between retracted and extended positions. The plug 16 in-fact comprises a number of circumferentially spaced dogs 24 which are located in corresponding

1 apertures 25 in the plug body 22 and the dog 24 shown in
2 Fig. 2 is in the retracted position.

3
4 The plug 16 also comprises a radially expandable seal
5 element 26 and a mandrel 28 which is adapted to be
6 translated relative to the plug body 22 both to urge the
7 locking dog 24 to the extended position, and to exert an
8 axial force on the seal element 26 to radially expand the
9 seal element, thereby locking and sealing the plug 16
10 within the tree bore 14. When it is desired to release
11 the plug 16 from the tree bore 14, the mandrel 28 is
12 returned downwardly, de-supporting the dogs 24, enabling
13 retraction of the dogs and facilitating return of the
14 seal 26 to the radially retracted or collapsed position
15 shown in Fig. 2.

16
17 The plug 16 and tree 10 will now be described in more
18 detail. The tree housing 20 includes a locking groove or
19 recess 30 in which the dogs 24 are engaged when the plug
20 16 is actuated. In a similar fashion, the tree housing 20
21 includes a recessed seal bore or groove 32 for providing
22 a metal-to-metal seal with the seal element 26, when the
23 plug 16 is actuated. It will be understood, however, that
24 the seal element may carry an elastomeric, plastic or
25 rubber seal surface, if desired.

26
27 The plug body 22 includes a main portion 34 and an upper
28 sub 36 which is coupled to the main portion 34 and is
29 axially movable relative to the main portion 34 through a
30 coupling 38, which is shown in more detail in the
31 enlarged perspective view of Fig. 3, where the sub 36 has
32 been removed, for clarity.

33

1 The coupling 38 includes an annular ring 40 which is
2 generally L-shaped in cross-section and which is
3 threadably coupled to an end 42 of the sub 36. The ring
4 40 is also movable along a recess 44 formed in the plug
5 main portion 34, permitting axial movement of the sub 36
6 relative to the main portion 34. However, a shoulder 46
7 on the main portion 34 prevents disengagement of the sub
8 36 from the main portion 34 by abutment with the ring 40.

9
10 The seal element 26 is threadably coupled at 47 to a
11 lower end 48 of the plug main portion 34 and defines an
12 end cap 50 of the plug 16. However, it will be understood
13 that the plug body 22 may form the end cap 50, with the
14 seal element 26 mounted on the plug body.

15
16 The seal element 26 is shaped to radially outwardly
17 expand when compressed by exertion of an axial force,
18 which, as will be described, is generated by the mandrel
19 28. This brings a sealing surface 52 of the seal element
20 26 into engagement with the recessed seal bore 32 of the
21 tree housing 20. The seal element 26 thus defines a zone
22 or region of deformation 54 where the seal element 26 is
23 deformed when compressed.

24
25 The seal element 26 shown in Fig. 2 is a one-piece
26 member, however, the seal element may be of the type
27 disclosed in the applicant's co-pending International
28 Patent Application No. PCT/GB2004/003631 (WO2005/022012),
29 the disclosure of which is incorporated herein by way of
30 reference. In accordance with the teachings of
31 PCT/GB2004/003631, an alternative seal element 26a is
32 shown in the enlarged, longitudinal half-sectional view
33 of Fig. 4, and includes an inner sleeve 56 and an outer

1 sleeve 58 which are joined at upper and lower ends 60,
2 62. A filler 64 is located between the sleeves 56, 58 and
3 is thus entirely contained within the sealing element 26a
4 and bounded on all sides by the metal sleeves 56, 58.
5 Thus an interior volume 66 defined by the sleeves 56, 58
6 contains the filler 64. The filler 64 is of a deformable
7 material and may be a plastic or elastomer.

8
9 The seal element 26a is shown in Fig. 5 after the ends
10 60, 62 have been brought together by compressing the seal
11 element, and the filler 64 supports the seal 26a to
12 prevent the seal from collapsing under applied pressure.
13 Figs. 6 and 7 show a further alternative seal element,
14 indicated generally by reference numeral 26b, both before
15 and following compression and deformation.

16
17 The mandrel 28 is axially movably mounted relative to the
18 plug body 22 and thus relative to main portion 34 and
19 upper sub 36, and includes a cam surface 68 for urging
20 the dogs 24 radially outwardly when the mandrel 28 is
21 moved upwardly. Also, the mandrel 28 includes a lower
22 flange or shoulder 70 which serves for compressing the
23 seal element 26 when brought into abutment with a
24 shoulder 72 on the seal element.

25
26 The plug 16 also includes a locking mechanism 74 which
27 includes an inner lock ring 76, and an outer lock ring 78
28 comprising a number of ring segments 80. The inner and
29 outer lock rings 76, 78 are shown in more detail in the
30 enlarged perspective views of Figs. 8 and 9,
31 respectively, as well as in Fig. 3.

32

1 The inner lock ring 26 includes a set of inner
2 protrusions in the form of ratchet teeth 82 and a set of
3 outer protrusions formed by a thread 84. The ratchet
4 teeth 82 engage corresponding ratchet teeth 86 on an
5 outer surface of the mandrel 28 and, as will be
6 described, serve for permitting movement of the mandrel
7 28 upwardly in a first direction A (Fig. 2) but
8 selectively restrict movement in a second, downward
9 direction B, (also Fig. 2) by co-operation with the outer
10 ring segments 80. To facilitate this, the outer ring
11 segments 80 include inner protrusions formed by a thread
12 88 which engage with the thread 84 on the inner ring 76.
13 In the position of Fig. 2, the outer ring 78 is axially
14 held between the plug shoulder 46 and a shoulder 90 on
15 the sub 36, and thus the ratchet teeth 86, 82 are
16 engaged, and the threads 84, 88 are engaged to restrict
17 movement of the mandrel 28 as described above.

18
19 The plug 16 also includes a pressure equalisation
20 assembly indicated generally by reference numeral 92,
21 which serves for equalising pressure between an interior
22 94 and an exterior 96 of the plug 16. The assembly 92
23 includes a passage 98 in the plug end cap 50 which is
24 initially closed by an annular shoulder or nub 100, and
25 an equalisation mandrel 102 which is movable within the
26 main mandrel 28 for selectively shearing the nub 100 to
27 open the passage 98. To achieve this, the mandrel 102
28 includes a cutter 104 and when sufficient axial load is
29 applied to the mandrel 102, the cutter 104 shears the nub
30 100, equalising pressure across the plug 16 through the
31 passage 98. As will be described, this facilitates safe
32 removal of the plug 16 from the tree 10, when it is
33 desired to re-open the tree.

1
2 Operation of the plug 16 in use will now be described in
3 detail, with reference also to Figs. 10 and 11, which
4 show the plug at later stages in a process of running,
5 setting, releasing and retrieving the plug.

6
7 The plug 16 is run-in to the tree bore 14 on a running
8 tool (not shown) in the configuration of Fig. 2, with the
9 dogs 24 retracted and the seal 26 in a radially
10 contracted position. This ensures that the dogs 24 and
11 seal 26 do not run against the tubing 18 and indeed that
12 they do not run against the walls of the locking groove
13 30 and recessed seal bore 32. The running tool engages a
14 fishing neck 108 of the sub 36, and includes a spear that
15 is designed to engage a similar fishing neck 110 of the
16 mandrel 28. The plug 16 is run-in on the running tool and
17 seated on a no-go 106 in the tree housing 20. The mandrel
18 28 is then moved upwardly relative to the plug body 22,
19 using the running tool to exert a force through the
20 fishing neck 110 that shears set screws 111. The mandrel
21 28 is thus moved upwardly to the position shown in Fig.
22 10 and the cam surface 68 urges the dogs 24 outwardly
23 into engagement with the locking groove 30, thereby
24 locking the plug 16 in the tree bore 14. Simultaneously,
25 the shoulder 70 on the mandrel 28 is brought into
26 abutment with the seal shoulder 72, axially compressing
27 the seal element 26 and deforming it, expanding it
28 radially outwardly to sealingly abut the recessed seal
29 bore 32, thereby sealing the plug 16 in the tree bore 14.
30 This upward movement of the mandrel 28 is retained
31 through the ratchet teeth 82, 86, which prevent return
32 downward movement of the mandrel 28. The upper plug 17 is
33 run, located and set in a similar fashion, and the plugs

1 16, 17 are thus located and sealed within the tree bore
2 14, providing a secure barrier, and the running tool is
3 then returned to surface and the tubing released from the
4 tree 10. Finally, a tree cap 117 is located on the tree
5 10, to provide an upper, outer barrier.

6
7 When it is desired to release the plug 16 from the tree
8 bore 14, a release tool (not shown) is run-in and latched
9 to the fishing neck 108 of the sub 36. The sub 36 is then
10 jarred upwardly, shearing screws 112 that couple the plug
11 main portion 34 and sub 36 together, and carrying the sub
12 36 upwardly to the position shown in Fig. 10. This brings
13 the ring 40 into abutment with a shoulder 46 on the main
14 portion 34, de-supporting the outer lock ring segments
15 80. The segments 80, which are resilient or sprung, then
16 move radially outwardly into a recess 114 defined by the
17 sub 36, bringing the threads 84, 88 out of engagement.
18 This effectively releases the mandrel 28, enabling return
19 downward movement of the mandrel 28 to release the dogs
20 24 and facilitate retraction of the seal element 26. This
21 is achieved by latching the release tool to the fishing
22 neck 110 of mandrel 28 and urging the mandrel downwardly
23 to the position of Fig. 11, carrying the inner lock ring
24 76. The plug 14 may then be returned to surface, re-
25 opening the tree bore 14.

26
27 In the preferred embodiments of the invention, pressure
28 is first equalised across the plug 16 before the mandrel
29 28 is moved downwardly to release the dogs 24 and retract
30 the seal element 26. This is achieved by providing the
31 release tool with a spear which abuts a collar 116 of the
32 inner mandrel 102 before engaging the main mandrel
33 fishing neck 110. In this fashion, when the release tool

1 is moved downwardly to engage the fishing neck 110, the
2 inner mandrel 102 is urged downwardly to shear the nub
3 100, opening fluid communication between the plug
4 interior 94 and exterior 96 through the passage 98,
5 through a port 118 in the inner mandrel 102. Thus
6 pressure is equalised before the main mandrel 28 can be
7 engaged and moved downwardly.

8
9 Turning now to Fig. 12, a plug in accordance with an
10 alternative embodiment of the present invention is shown,
11 the plug indicated generally by reference numeral 16'.
12 Like components of the plug 16' with the plug 16 of Figs.
13 2-11 share the same reference numerals with the addition
14 of suffix', and only the differences between the plugs
15 16' and 16 will be described herein.

16
17 The plug 16' includes an alternative inner pressure
18 equalisation mandrel 102' which includes a collet 120 at
19 an upper end having collet fingers 122. The collet
20 fingers 122 are designed to snap into a collet recess or
21 groove 124 in the main mandrel 128' to retain movement of
22 the inner mandrel 102' following shearing of the nub
23 100'.

24
25 Various modifications may be made to the foregoing
26 without departing from the spirit and scope of the
27 present invention.

28
29 The principles of the tree plug described above may be
30 applied equally in relation to a downhole lock or
31 downhole plug for location and use in other downhole
32 tubing, such as casing, liner or some other tubing
33 string, and may for example serve for locating a string

1 of tubing or a tool for conducting a completion or
2 intervention operation.

3
4 The seal element may be of any suitable shape and may be
5 one-piece or comprised of a number of separate
6 components. Even where the seal element is one-piece, the
7 seal element may be made up of a number of sections or
8 portions bonded or otherwise coupled together. In place
9 of the expandable seal element described above, a more
10 conventional type of seal element may be provided, such
11 as an annular elastomeric, rubber or other seal which may
12 be actuated in a similar manner, by compression using the
13 mandrel of the plug. Alternatively, the mandrel may be
14 arranged to exert a radially outwardly directed force
15 upon the seal element of this alternative type, for
16 example, by an arrangement of cam surfaces, ramps or the
17 like.

18
19 It will be understood that the locking recess and
20 recessed seal bore in the tree may be retro-fitted to the
21 tree or provided in the tree as supplied.

22
23 A suitable, alternative locking arrangement may be
24 provided such as an alternative locking mechanism, and an
25 alternative set or type of locking dogs may be provided.
26 Furthermore, any suitable number of seal elements and/or
27 locking dogs may be provided, for example, the plug may
28 comprise a plurality of seal elements of different types
29 such as a seal element suitable for providing a metal-to-
30 metal seal and an elastomeric, plastics or rubber seal or
31 any desired combination thereof.

1 CLAIMS

- 2
- 3 1. A tree plug for a tree having a main tree bore, the
4 tree plug comprising:
5 a plug body;
6 at least one locking member mounted for radial
7 movement relative to the plug body between retracted
8 and extended positions;
9 at least one radially expandable seal element; and
10 a mandrel adapted to be translated relative to the
11 plug body to urge the locking member to the extended
12 position and to exert an axial force on the seal
13 element to radially expand the seal element, to
14 thereby lock and seal the plug within the tree bore.
15
- 16 2. A tree plug as claimed in claim 1, wherein the
17 mandrel is upwardly movable relative to the plug
18 body for urging the locking member to the extended
19 position and for exerting the axial force on the
20 seal element.
21
- 22 3. A tree plug as claimed in either of claims 1 or 2,
23 wherein the plug comprises a pressure equalisation
24 assembly for selectively equalising pressure between
25 an interior and an exterior of the plug.
26
- 27 4. A tree plug as claimed in claim 3, wherein the
28 pressure equalisation assembly comprises a pressure
29 equalisation passage for facilitating pressure
30 equalisation.
31

- 1 5. A tree plug as claimed in claim 4, wherein the
2 passage is normally closed and is adapted to be
3 selectively opened for pressure equalisation.
4
- 5 6. A tree plug as claimed in any one of claims 3 to 5,
6 wherein the equalisation assembly comprises a
7 pressure equalisation mandrel mounted for movement
8 with respect to the plug body, for equalising
9 pressure between the plug interior and exterior.
10
- 11 7. A tree plug as claimed in claim 6, wherein the
12 pressure equalisation mandrel is adapted to
13 selectively open the passage on movement of the main
14 mandrel with respect to the plug body.
15
- 16 8. A tree plug as claimed in claim 4, or any one of
17 claims 5 to 7 when dependent on claim 4, wherein the
18 passage is formed in the plug body and an internal
19 end of the passage is closed by a shoulder on an
20 internal wall of the plug body.
21
- 22 9. A tree plug as claimed in claim 8, wherein the
23 pressure equalisation mandrel is adapted to shear
24 the shoulder on movement of the pressure
25 equalisation mandrel with respect to the plug body,
26 to open the passage.
27
- 28 10. A tree plug as claimed in any one of claims 3 to 9,
29 wherein the pressure equalisation mandrel is
30 dimensioned and located within the main mandrel such
31 that when it is desired to release the plug, the
32 pressure equalisation mandrel is moved to equalise
33 pressure between the interior and exterior of the

1 plug before the main mandrel is moved to release the
2 locking member and the seal element.

3
4 11. A tree plug as claimed in any preceding claim,
5 wherein the plug comprises a locking mechanism for
6 restraining the mandrel, and thus for restraining
7 the locking member in the extended position and the
8 seal element in the radially expanded position.

9
10 12. A tree plug as claimed in claim 11, wherein the
11 locking mechanism is adapted to permit movement of
12 the mandrel in a first axial direction with respect
13 to the plug body and to restrain movement of the
14 mandrel in a second, opposite axial direction.

15
16 13. A tree plug as claimed in either of claims 11 or 12,
17 wherein the locking mechanism comprises a lock ring
18 serving for restraining movement of the mandrel
19 relative to the plug body.

20
21 14. A tree plug as claimed in claim 13, wherein the lock
22 ring is a one-piece ring.

23
24 15. A tree plug as claimed in claim 13, wherein the lock
25 ring comprises a plurality of lock ring segments.

26
27 16. A tree plug as claimed in any one of claims 13 to
28 15, wherein the lock ring is provided between the
29 mandrel and the plug body, and comprises a plurality
30 of ratchet teeth adapted to engage corresponding
31 teeth on the mandrel.

32

- 1 17. A tree plug as claimed in claim 16, wherein the
2 ratchet teeth of the lock ring and the mandrel are
3 shaped to permit movement of the mandrel with
4 respect to the plug body in a first axial direction
5 and to restrain the mandrel against movement in a
6 second axial direction.
7
- 8 18. A tree plug as claimed in any one of claims 13 to
9 17, wherein the lock ring forms an inner ring and
10 the locking mechanism also comprises an outer lock
11 ring, the inner and outer lock rings adapted to co-
12 operate to selectively restrain the mandrel against
13 movement with respect to the plug body.
14
- 15 19. A tree plug as claimed in claim 18, wherein the
16 outer lock ring comprises a plurality of locking
17 segments, the outer locking segments adapted to be
18 located between the inner lock ring and the plug
19 body.
20
- 21 20. A tree plug as claimed in claim 19, wherein the
22 outer locking segments define a thread for engaging
23 a corresponding thread on an outer surface of the
24 inner lock ring, interengagement between the outer
25 locking threads and the threads on the inner lock
26 ring, and between the inner lock ring ratchet teeth
27 and the mandrel ratchet teeth serving for together
28 restraining the mandrel against movement with
29 respect to the plug body.
30
- 31 21. A tree plug as claimed in any one of claims 18 to
32 20, wherein the outer lock ring is selectively

radially moveable in order to permit movement of the mandrel with respect to the plug body.

22. A tree plug as claimed in any one of claims 18 to 21, wherein the outer lock ring is resilient and at least initially held in a stressed configuration until permitted to radially move relative to the mandrel.

23. A tree plug as claimed in any preceding claim, wherein the plug body comprises a main plug body portion and a second portion coupled to the main plug body portion and selectively moveable with respect thereto.

24. A tree plug as claimed in claim 23, when dependent on claim 19, wherein the second portion defines an internal recess for receiving the outer lock ring segments, to facilitate radial movement of the segments and thus release of the mandrel when the sub is moved axially relative to the main plug body portion to align the segments with the recess.

25. A tree plug as claimed in any preceding claim, wherein the seal element is adapted to be axially compressed and thus shortened in length when an axial force is exerted on the seal element by the mandrel, thus urging the seal element outwardly into sealing contact with the tree bore.

26. A tree plug as claimed in any preceding claim, wherein the seal element has a wall of a reduced wall thickness in a region of the seal element to be

1 deformed into sealing contact with the tree bore,
2 relative to a remainder of the seal element.
3

4 27. A tree plug as claimed in claim 26, wherein an
5 axially central region of the seal element is of a
6 wall thickness which is reduced relative to regions
7 of the seal element spaced from said central region.
8

9 28. A tree plug as claimed in any preceding claim,
10 wherein the seal element defines a zone of
11 deformation where the element is adapted to be urged
12 into sealing contact with the tree bore.
13

14 29. A tree plug as claimed in any preceding claim,
15 wherein the seal element comprises: an inner
16 deformable surface, an outer deformable surface, the
17 inner and outer surfaces being joined at opposed
18 first and second ends providing a body defining an
19 interior volume entirely bounded by the said
20 surfaces and said ends, a deformable filler material
21 within said interior volume, wherein the element
22 deforms in a predetermined manner to seal between
23 the first and second surfaces when said ends are
24 brought toward each other.
25

26 30. A tree plug as claimed in any preceding claim,
27 wherein the locking member and the seal element are
28 adapted to engage corresponding lock and seal
29 recesses provided in the tree bore.
30

31 31. A tree plug as claimed in any preceding claim,
32 wherein the plug comprises a plurality of locking

members located in radially extending recesses in the plug body.

32. A tree plug as claimed in any preceding claim, wherein the locking member comprises a cam surface adapted to co-operate with a corresponding surface on the mandrel, such that the mandrel urges the locking member radially outwardly on translation of the mandrel relative to the plug body.

33. A tree comprising:
a main tree bore and a tree plug located in the tree bore and sealed relative to the bore, the tree plug comprising a plug body; at least one locking member mounted for radial movement relative to the plug body between retracted and extended positions; at least one radially extendable seal element; and a mandrel adapted to be translated relative to the plug body to urge the locking member to the extended position to engage a latch recess in the tree bore and to exert an axial force on the seal element to radially expand the seal element to engage a seal recess in the tree bore, to thereby lock and seal the plug within the tree.

34. A downhole plug adapted to be located in downhole tubing, the plug comprising:
a plug body;
at least one locking member mounted for radial movement relative to the plug body between retracted and extended positions;
at least one radially expandable seal element; and

1 a mandrel adapted to be translated relative to the
2 plug body to urge the locking member to the extended
3 position and to exert an axial force on the seal
4 element to radially expand the seal element, to
5 thereby lock and seal the plug within the downhole
6 tubing.

7
8 35. A downhole lock adapted to be located in downhole
9 tubing, the downhole lock comprising:
10 a main body;
11 at least one locking member mounted for radial
12 movement relative to the main body between retracted
13 and extended positions;
14 at least one radially expandable seal element; and
15 a mandrel adapted to be translated relative to the
16 main body to urge the locking member to the extended
17 position and to exert an axial force on the seal
18 element to radially expand the seal element, to
19 thereby lock and seal the downhole lock within the
20 downhole tubing.

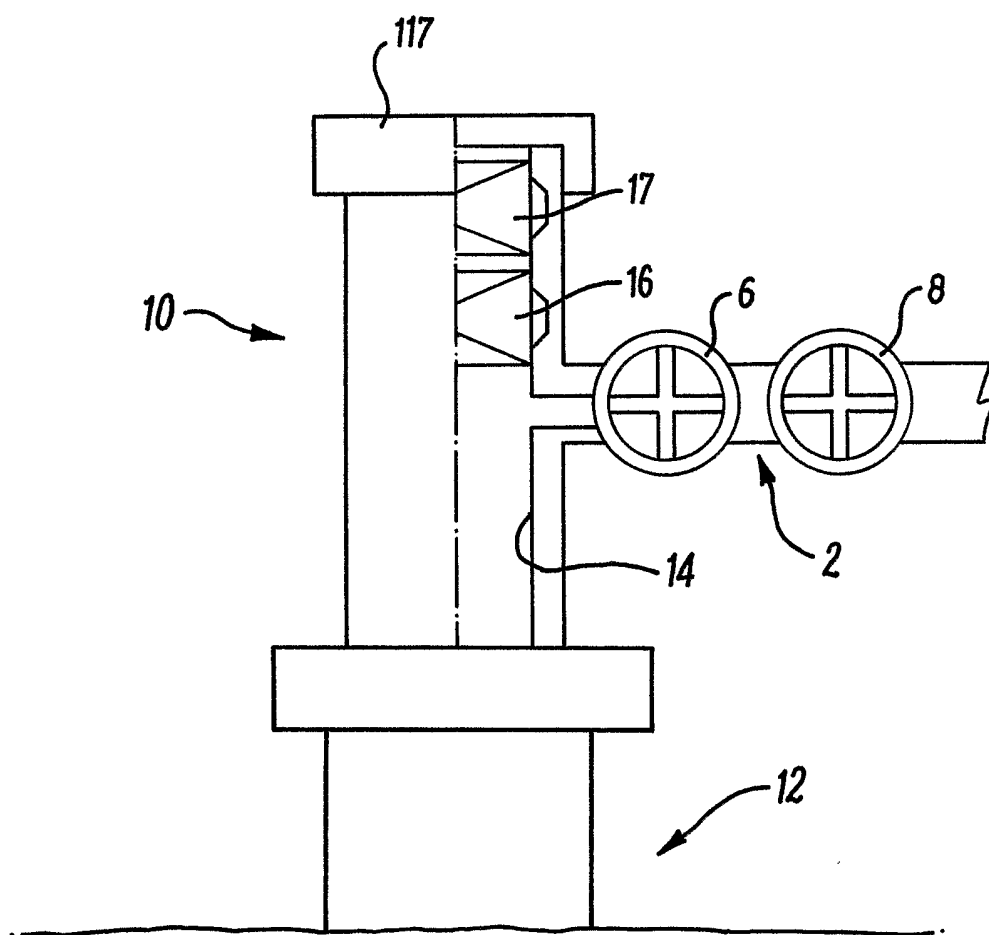
21
22 36. A method of plugging a tree bore comprising the
23 steps of:
24 locating a tree plug within the tree bore;
25 translating a mandrel of the tree plug relative to a
26 body of the plug, to urge a locking member mounted
27 for radial movement relative to the plug body from a
28 retracted to an extended position to cause the
29 locking member to engage a latch recess in the tree
30 bore, and to exert an axial force on a seal element
31 of the plug to radially expand the seal element into
32 sealing abutment with a seal recess in the tree

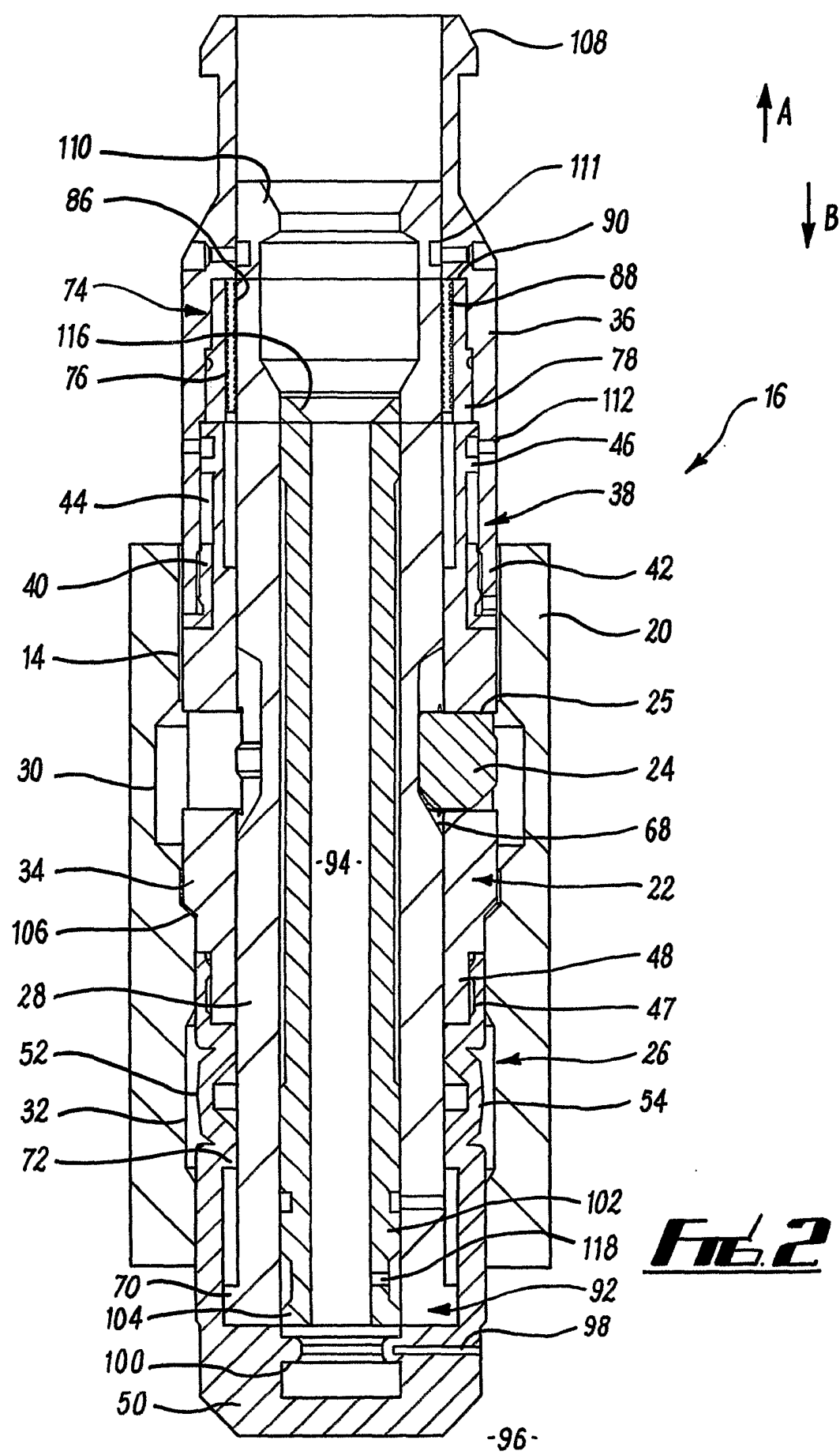
bore, to thereby lock and seal the plug within the tree.

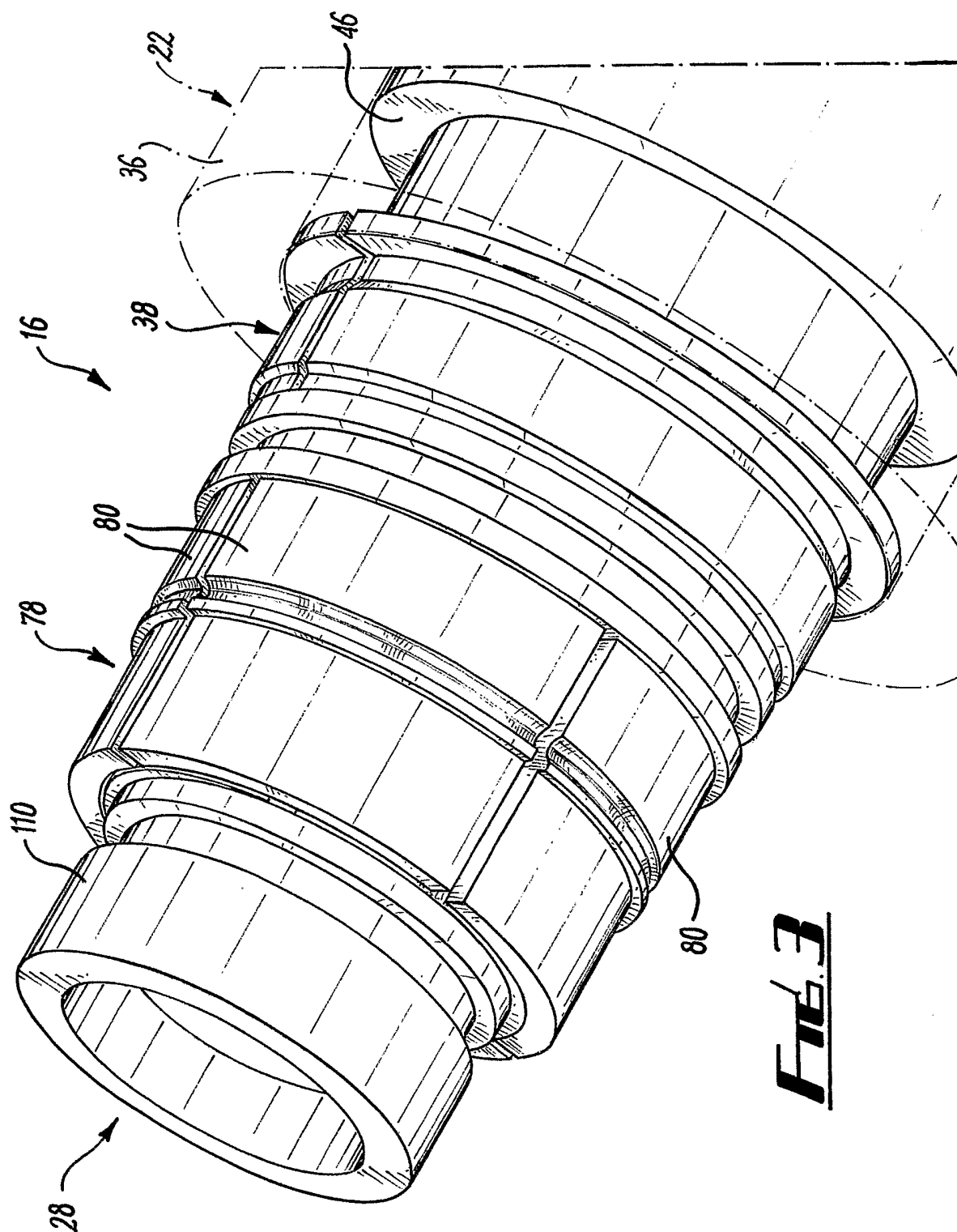
37. A tree plug for a tree having a main tree bore, the tree plug comprising:
a plug body;
at least one locking member mounted for radial movement relative to the plug body between retracted and extended positions;
at least one radially expandable seal element; and
a mandrel adapted to be translated upwardly relative to the plug body to urge the locking member to the extended position and to radially expand the seal element, to thereby lock and seal the plug within the tree bore.

38. A tree plug for a tree having a main tree bore, the tree plug comprising:
a plug body;
at least one locking member mounted for radial movement relative to the plug body between retracted and extended positions;
at least one radially expandable seal element;
a mandrel adapted to be translated relative to the plug body to urge the locking member to the extended position and to radially expand the seal element, to thereby lock and seal the plug within the tree bore;
and
a locking mechanism comprising an inner lock ring having a set of inner protrusions for engaging corresponding outer protrusions on the mandrel, and an outer lock ring having a set of inner protrusions for engaging corresponding outer protrusions on the

1 inner lock ring, interaction between the outer lock
2 ring protrusions, the inner lock ring protrusions
3 and the mandrel protrusions permitting movement of
4 the mandrel in a first direction relative to the
5 plug body and restraining the mandrel against
6 movement in a second, opposite direction to thereby
7 restrain the locking member in the extended position
8 and the seal element in a radially expanded
9 position;
10 wherein the outer lock ring is selectively radially
11 outwardly moveable to disengage the outer lock ring
12 protrusions and the outer protrusions on the inner
13 lock ring, to permit movement of the mandrel in said
14 second direction to release the plug.

**FIG. 1**





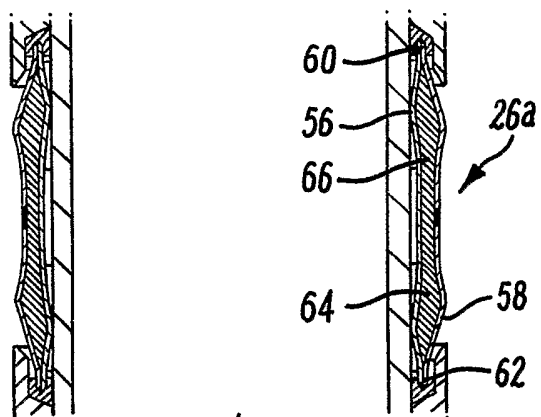


FIG. 4

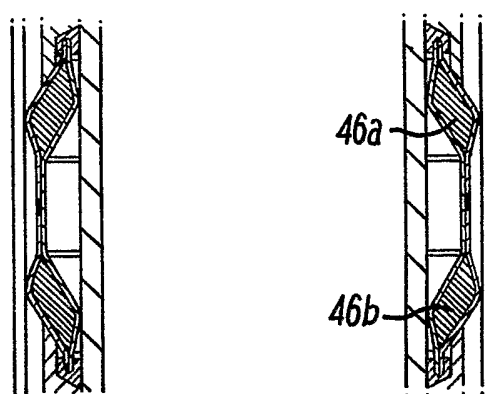


FIG. 5

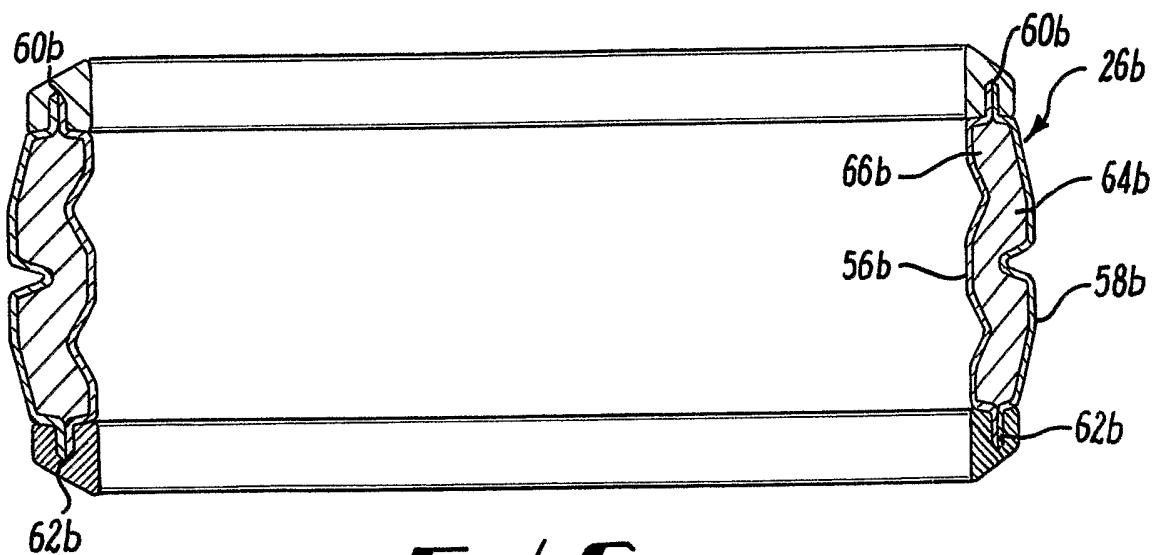


FIG. 6

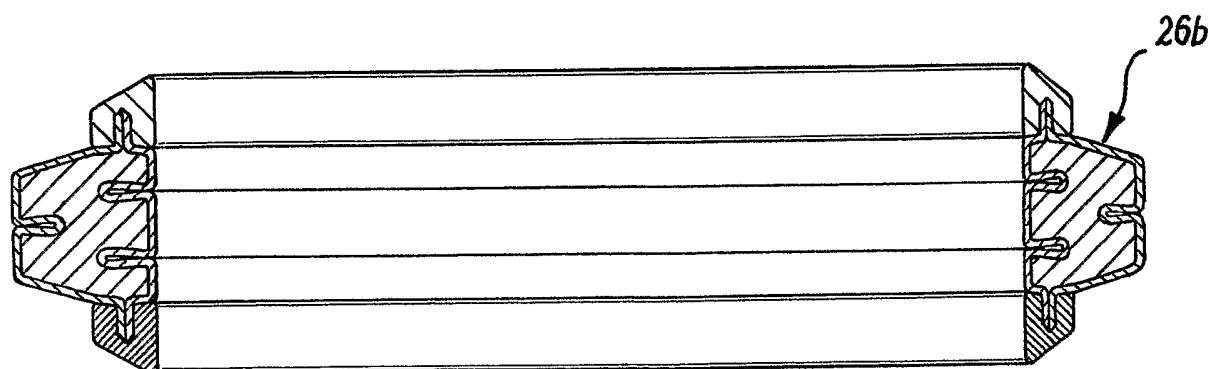
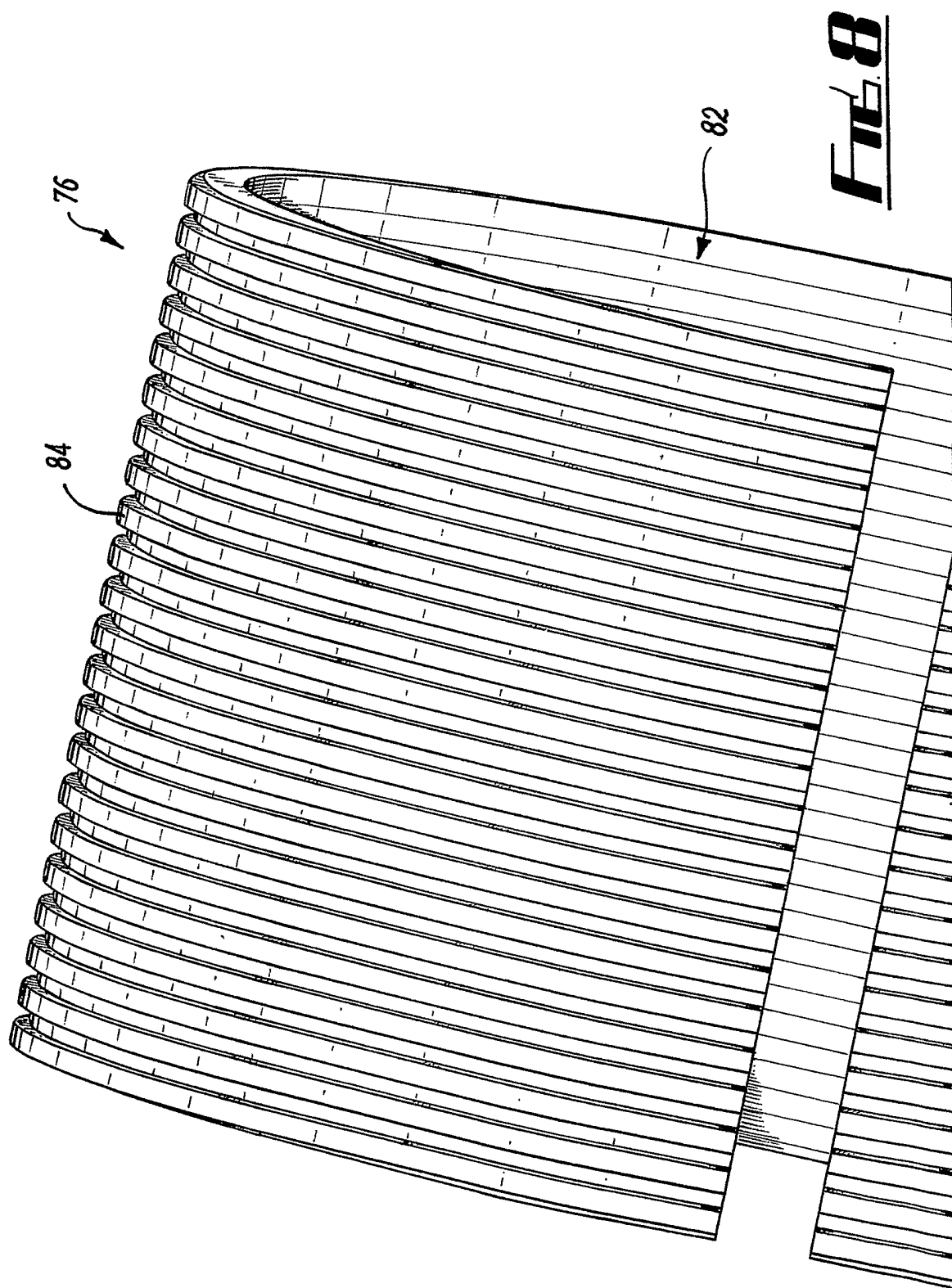


FIG. 7



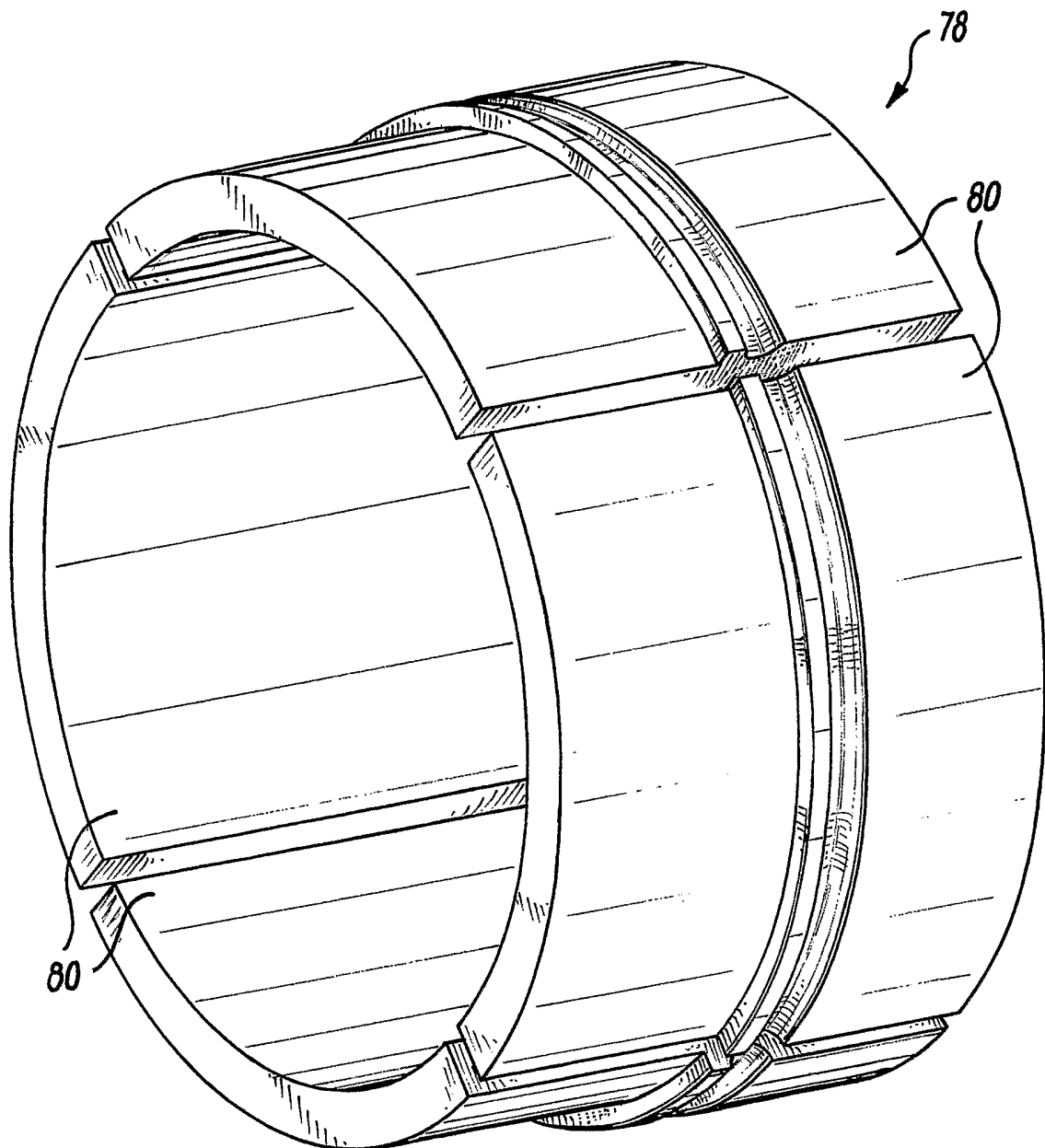


FIG. 9

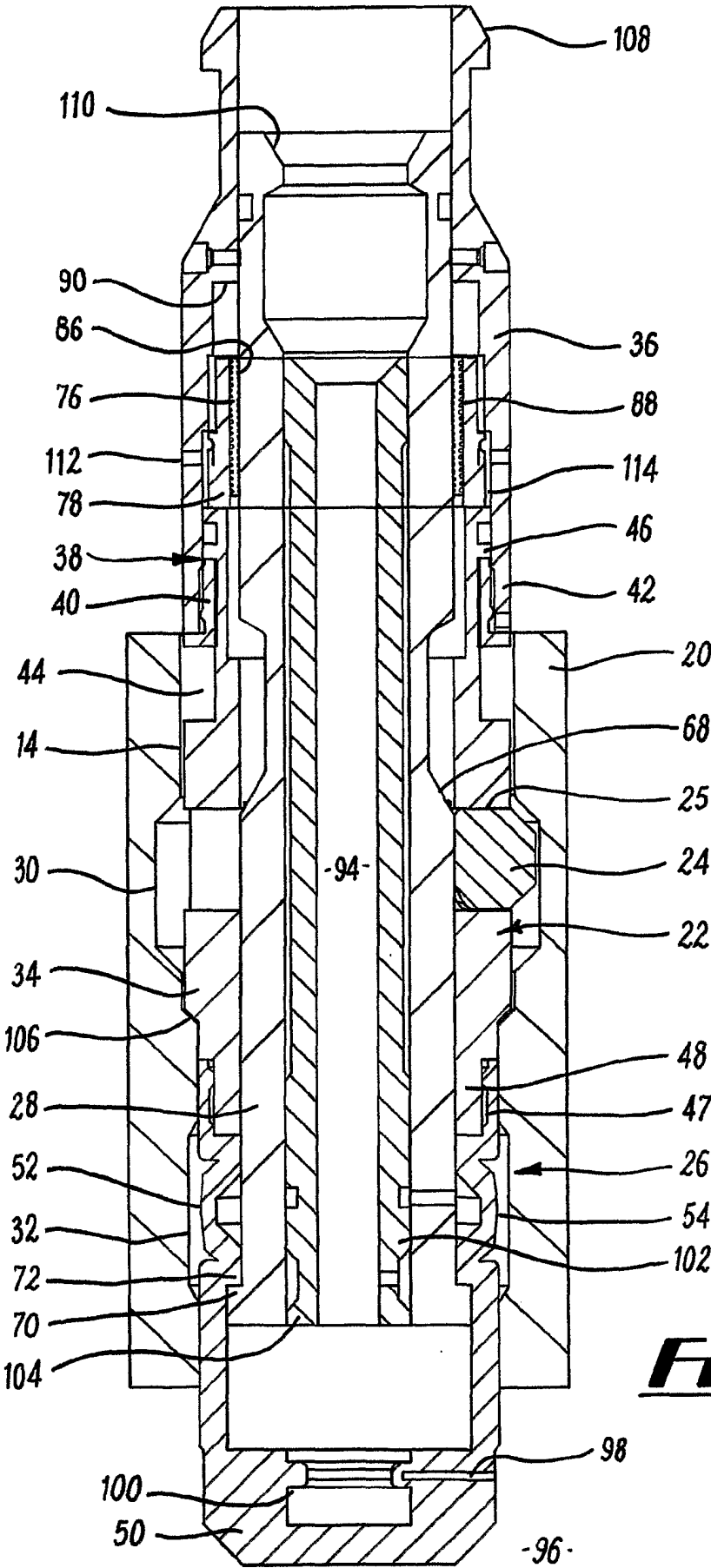
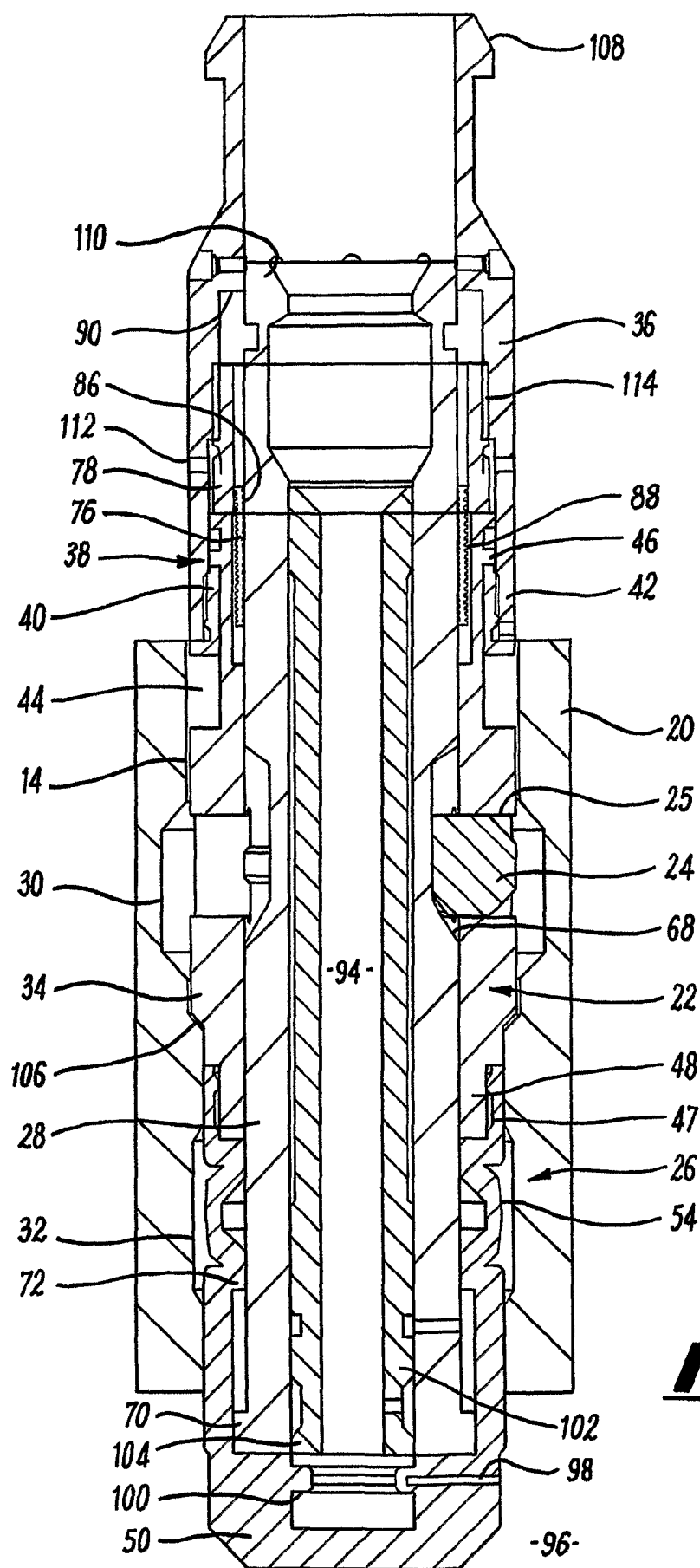
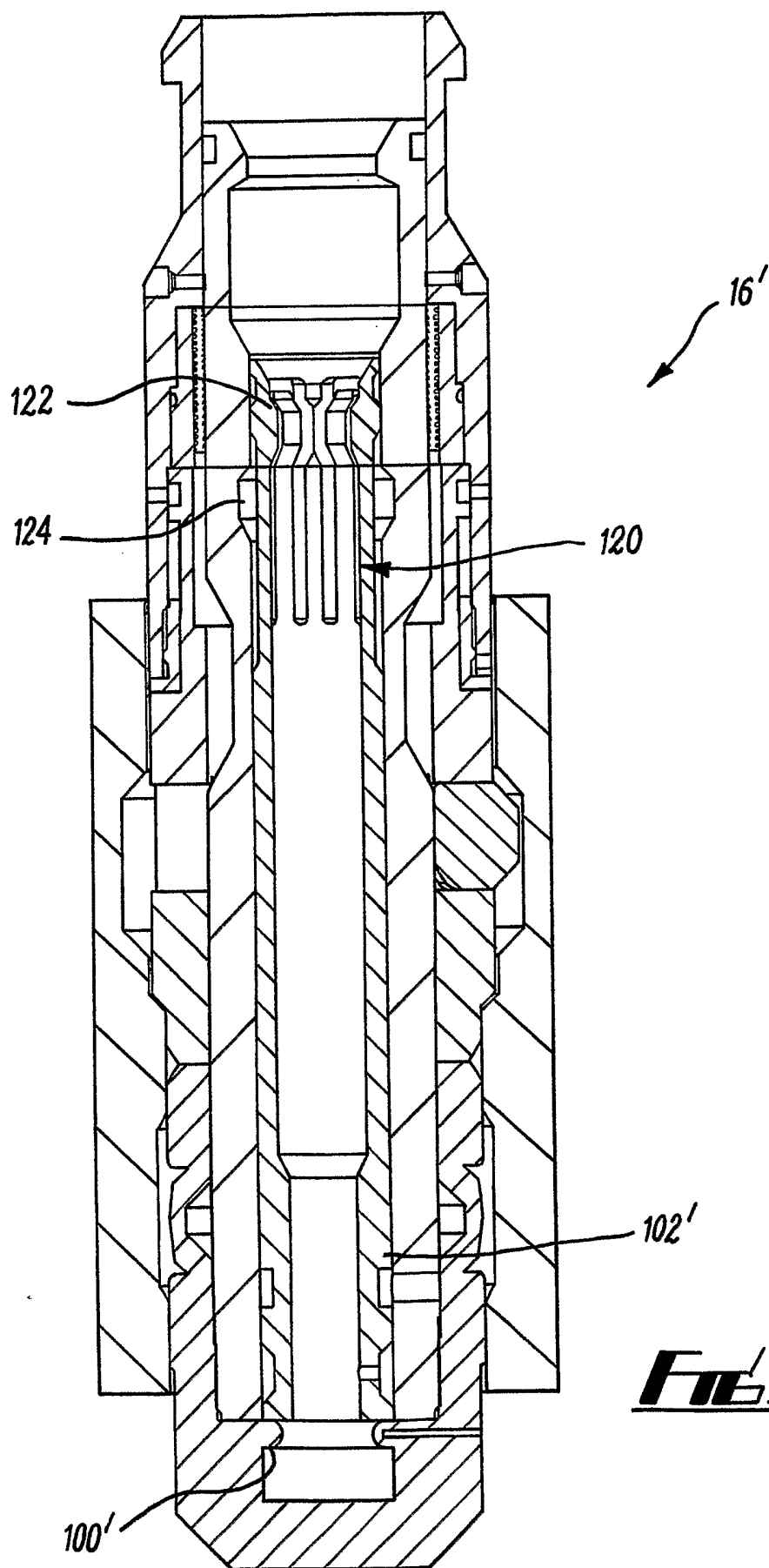


Fig. 10

**FIG. 11**

***FIG. 12***

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2006/000815

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B33/043 E21B33/035

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E21B

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 163 514 A (JENNINGS ET AL) 17 November 1992 (1992-11-17) column 3, line 1 - column 4, line 41; claim 1; figures 1,2 -----	1,33-38
X	US 4 058 162 A (SMITH ET AL) 15 November 1977 (1977-11-15) column 5, line 53 - column 7, line 31; claim 1; figures 1-3 -----	1,33-38
X	US 4 116 277 A (MCGEE ET AL) 26 September 1978 (1978-09-26) claims 1-3 -----	1,33-38
X	EP 0 715 056 A (COOPER CAMERON CORPORATION) 5 June 1996 (1996-06-05) column 14, line 45 - column 15, line 16; claim 1; figures 11,11a -----	1,33-38
	-/--	

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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P document published prior to the international filing date but later than the priority date claimed

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

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

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

& document member of the same patent family

Date of the actual completion of the international search

28 June 2006

Date of mailing of the international search report

04/07/2006

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INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2006/000815

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 928 761 A (GAZDA ET AL) 29 May 1990 (1990-05-29) the whole document	1-38
A	US 2004/163818 A1 (FENTON STEPHEN P ET AL) 26 August 2004 (2004-08-26) paragraphs [0038] - [0040]; figure 3	1-38

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2006/000815

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