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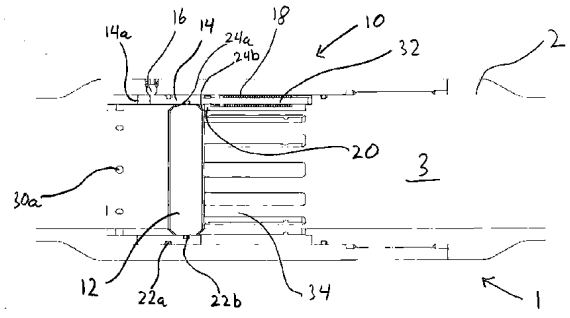
(54) Title **Plug breaking mechanism**

(57) Abstract

A plug breaking mechanism (10) for breaking a plug (12) that is sealing of a through bore (3) in a well tool device (1), comprising:
- a plug (12) disposed inside a housing (2) and axially slidable within a limited interval inside the housing (2),
- a seal ring (14) inside the housing (2) between the plug (12) and the housing (14), where it can slide axially between a first position and a second position and seals between the plug (12) and the housing (2), the seal ring (14) comprises a seal ring uphole piston area (14a) exposed to the pressure above the plug (12),
- one or more shear elements (16) with a given shear value preventing axial movement of the seal ring (14) inside the housing (2) prior to shearing the shear element (16),
- one or more biasing members (18) acting on said seal ring (14) in an uphole direction,
- one or more breaking members (20) physically separated from the plug (12) with the seal ring (14) in its first position and exposed to the plug (12) with the seal ring (14) in its second position.



TITLE: Plug breaking mechanism

Field of the invention

The invention relates to a plug breaking mechanism for breaking a plug that is sealing of a through bore in a well tool device.

Background of the invention.

The present invention relates to a packer setting device. Packer setting devices are used as a temporary barrier in a production tubing to be able to pressure up the production tubing for the purpose of setting a packer to seal of the annulus between the production tubing and a casing. The invention can for example also be installed to pressure test production tubing, or as a temporary well barrier while performing other commission activities in the well. The application is to be used in downhole installations.

Disclosure of the state of art.

Prior art includes various solutions for holding a glass-seat or a glass-plug in a housing to enable well operations like pressure test, packer setting and other. After well operations are completed, a mechanism for releasing and breaking the glass is required.

Other solutions incorporate the following mechanisms:

- Break glass by intervention - mill or spear glass to break
- Shear out glass by predetermined pressure threshold
- Shear out glass activated by a pressure cycle counter system, typical a counter system that releases a holding and breaking mechanism at the predetermined number of pressure cycles

WO2017034416 (A1) relates to a plug arrangement comprising glass arranged in one or more seats in a plug housing, the seat or seats forming support members supporting the glass or glasses in an axial direction. The invention is, among others, characterized in that at least one of the support members comprises an axially displaceable split sleeve which, in one direction, comprises a support ring/face

abutting against the glass, and in the other direction a number of split sleeve arms arranged to rest against an edge arranged in the plug housing.

WO2014154464 (A2) relates to a disintegratable plug apparatus for use in connection with petroleum wells, especially during pressure testing of such petroleum wells.

Prior art also includes: NO336554 B1, NO340829 B1, NO342911 B1, NO343274 B1 and NO20150701 A1.

Objects of the present invention

One object for the invention is to provide a reliable method for breaking a plug in a well toll device without the need for intervention.

Another object for the invention is to provide a well tool device that can act as a barrier to pressure up against for performing a pressure test of the production tubing and for setting a packer.

Yet another object for the invention is to provide a well tool device that can act as a formation barrier.

Yet another object for the invention is to provide a well tool device that can act as a casing floatation device to reduce drag and friction forces during casing installation.

Summary of the invention

At least some of the above mention objects is attempted solved with a plug breaking mechanism for breaking a plug that is sealing of a through bore in a well tool device. The plug breaking mechanism comprises:

- a plug disposed inside a housing and axially slidable within a limited interval inside the housing,
- a seal ring inside the housing between the plug and the housing, where it can slide axially between a first position and a second position and seals between

the plug and the housing, the seal ring comprises a seal ring uphole piston area exposed to the pressure above the plug,

- one or more shear elements with a given shear value preventing axial movement of the seal ring inside the housing prior to shearing the shear element,
- one or more biasing members acting on said seal ring in an uphole direction,
- one or more breaking members physically separated from the plug with the seal ring in its first position and exposed to the plug with the seal ring in its second position.

The one or more shear elements can be one or more shear pins.

The seal ring can comprises at least one housing seal and at least one plug seal.

The biasing member can be a spring.

The limited interval inside the housing where the plug can travel can in a starting position be limited by a uphole slanted ledge, and a downhole slanted ledge.

The plug can be made of glass.

The biasing member can act on a biasing rod that can transfer the force from the biasing member to push the seal ring in the uphole direction.

A downhole slanted ledge for limiting the plugs travel with the seal ring in its starting position can be made up by a number of tips on a number of collet fingers.

The plug can be prevented from further downhole movement by a number of collet fingers that get radial support from the seal ring, and after the seal ring moves and the collet fingers lose radial support the plug can be forced in the downhole direction against one or more breaking members.

The plug breaking mechanism can comprises a support ring with a downhole slanted ledge placed below the plug in the through channel and the support ring is given axially support in the downhole direction by balls or segments that partly protrudes into the through channel and the balls or segments are prevented from yielding radially by the seal ring.

A seal ring downhole piston area can be exposed to the pressure of the through channel below the plug.

The plug breaking mechanism can comprises a ratchet lock ring fixed to the housing and a ratchet c-ring that moved axially with the seal ring.

The ratchet lock ring and the ratchet c-ring can be locked together when the seal ring is in the second position.

The plug breaking mechanism can comprises a breaking ring placed below the seal ring, with breaking members that protrudes axially into the seal ring.

Description of the diagrams

Embodiments of the present invention will now be described, by way of example only, with reference to the following diagrams wherein:

Figure 1a - f shows a first embodiment of the invention

Figure 2a - e shows a second embodiment of the invention.

Figure 3a – h shows a third embodiment of the invention.

Figure 4a – e shows a fourth embodiment of the invention.

Figure 5a – f shows a fifth embodiment of the invention.

Figure 6 shows a possible embodiment of a lock ring that can be used as part of the invention.

Figure 7a and b shows two possible embodiments of plugs that can be used as part of the invention.

Figure 8a and b shows two possible embodiments of obturator seats that can be used as part of the invention.

Figure 9 shows a possible embodiment of a seal ring together with a break ring equipped with breaking members.

Figure 1-5 shows different embodiments of the well tool device and of the plug breaking mechanism. Figure 1-5 are all oriented with the path to surface to the left in the figure. The left side of these figures will hereafter be referred to as the uphole direction or uphole side. The right side of the figures will naturally be the direction to the toe of the well, hereafter referred to as the downhole direction or downhole side.

The directions up and down refers to uphole and downhole respectively, and above and below also refers to a position that is respectively in the uphole direction or in the downhole direction from something.

Description of preferred embodiments of the invention

The invention relates to a well tool device 1 for use in a downhole tubular string that can be used for exploiting hydrocarbon resources. The well tool device 1 comprises a housing 2 with a through bore 3. Inside the housing 2 a breakable plug 12 or seat is placed for sealing of the through bore 3 or for at least restrict the through bore 3. Fig 7a and 7b shows possible embodiments of plugs and Fig. 8a and 8b shows possible embodiments of seats. For simplicity, the term plug 12 is hereafter both used for å solid plug and for a seat for accommodating an obturator 4. Further a plug breaking mechanism 10 is accommodated inside the housing 2.

The plug breaking mechanism 10 comprises a seal ring 14 accommodated inside the housing 2. The seal ring is equipped with one or more housing seals 22a, to seal of between the housing 2 and the seal ring 14. The seal ring 14 is also equipped with one or more plug seals 22b which seals against the plug 12 that is placed inside the seal ring 14.

The seal ring is fixed in its position relative to the housing 2 by one or more shear elements 16. The shear elements 16 can be shear pins or shear screws or any other shear elements that is obvious for one skilled in the art. The shear elements 16 is designed to shear off when exposed to a shear force greater than the shear value it is designed for. When the shear element 16 is sheared the seal ring 14 can move up and down inside the housing 2. A force for moving the seal ring 14 in the downhole direction can be applied on the seal ring 14 by pressuring up the through bore 3 above the plug 12. The pressure will then act on a seal ring uphole piston area 14a. If a high enough pressure is applied the shear value of the shear element 16 will be exceeded and the shear elements 16 shears. The seal ring 14 will then be able to move up and down a limited distance within the housing 2.

The plug breaking mechanism 10 also comprises a biasing member 18 acting with a force on the seal ring 14. The force is directed in the uphole direction. The biasing member 18 will thus urge the seal ring 14 in an uphole direction. The seal ring will not move in the uphole direction as long as there are one or more shear elements 16

fixing the seal ring 14 or as long as there is a force greater than the biasing force acting on the seal ring uphole piston area 14a.

The plug 12 is as mentioned placed inside the seal ring 14. The plug 12 can slide up and down inside the seal ring 14 a limited distance.

The seal ring 14 can as mentioned slide up and down a limited distance inside the housing 2, and the plug can slide up and down relative to the seal ring 14 within a limited distance which is fully or partly inside the seal ring 14. The plug 12 is limited in the uphole direction by the uphole slanted ledge 24a, and the plug is limited in the downhole direction by a downhole slanted ledge 24b. The interval which the plug 12 can travel might change depending on the position of the seal ring 14. In the starting position of the seal ring 14, the plug might not be able to move at all.

The seal ring 14 is in a starting position when the shear elements 16 is intact. The seal ring 14 can slide between a first position that is in the downhole direction from the starting position and a second position that is in the uphole direction from the starting position.

When the seal ring is in its second position one or more breaking members 20 is exposed to the plug 12. What is meant by the term exposed to the plug 12 is that the breaking member 20 no longer is physically separated from the plug. Pressure difference across the plug and seal ring can bring the plug and breaking member in contact with each other.

With the breaking member 20 exposed the breaking member 20 and the plug 12 can be brought together to break the plug 12. The plug 12 can be made of glass or some other brittle material, that can break as the plug and breaking member is brought together.

In a first possible embodiment of the plug breaking mechanism 10 showed in fig. 1 a-f the plug breaking mechanism comprises collet fingers 34. The collet fingers 34 is bendable and can yield radially outwards when loosing radial support. The tip of the collet fingers are slanted as seen in figure 1f and makes up the downhole slanted ledge 24b. When the seal ring 14 is in the starting position or in the first position the seal ring 14 provided radial support for the collet fingers 34 preventing them from yielding radially outwards.

Further, the plug breaking mechanism in this embodiment comprises a biasing rod 32, which is in contact with the biasing member 18 and with the seal ring 14. The biasing rod 32 transfers the biasing force from the biasing member 18 to the seal ring 14.

With the shear element 16 intact and seal ring 14 in its starting position the tip (downhole slanted ledge 24b) of the collet fingers 34 and the uphole slanted ledge 24a will limit the axial travel of the plug 12.

With reference to fig. 1a-f the sequence for breaking the plug will be explained.

In figure 1a the seal ring 14 is in its starting position with the shear element 16 intact, the collet fingers 34 are prevented from bending radially outwards and the plug 12 is confined between the uphole slanted ledge 24 and the tip of the collet fingers 34.

In figure 1b pressure have been applied on the uphole side of the plug 12. A force greater than the shear value of the shear elements 16 and the biasing force of the biasing member 18 combined have acted on the seal ring uphole piston area 14a and forced the seal ring 14 in a downhole direction into its first position.

In figure 1c the pressure on the uphole side of the plug 12 is bleed down. The biasing member 18 will via the biasing rod 32 push the seal ring 14 in an uphole direction into its second position. The collet fingers 34 has now lost radial support and can yield radially outwards.

In figure 1d pressure is again applied on the uphole side of the plug 12. The plug 12 will be move downwards against the slanted tips of the collet fingers 34, forcing the collet fingers 34 to yield radially outwards and exposing one or more breaking members 20.

In figure 1e the plug is forced against one or more breaking members. If needed the pressure can be increased to get sufficient force to break the plug 12.

In figure 1f the plug 12 is shattered and the through channel 3 is open.

In a second possible embodiment of the plug breaking mechanism 10 showed in fig. 2a-e the collet fingers from figure 1 is replaced by a support ring 26 held in place by balls 28. Instead of balls 28, segments can be used, but for the convenience of the reader the term balls 28 are used in the rest of the text.

The support ring 26 prevents the plug 12 from further movements in a downhole direction. The balls 28 protrudes into the through channel 3 and provides axial support for the support ring 26 in the downhole direction. The seal ring 14 provided radial support for the balls 28 and prevents them from falling into a radial grove in the wall of the housing 2. As long as the seal ring 14 is in the starting position with the shear element 16 intact the plug 12 is limited to slide between the uphole slanted ledge 24a and the support ring 26 with the downhole slanted ledge 24b.

In the second embodiment the breaking member 20 is in the form of one or more breaking pins protruding the support ring 26. When the support ring 26 slides in a axial downhole direction the breaking member 20 in this case the breaking pins will be exposed to the plug 12.

With reference to fig. 2a-e the sequence for breaking the plug 12 will be explained.

In figure 2a the seal ring 14 is in its starting position with the shear element 16 intact, the support ring 26 is prevented from moving in the downhole direction by the balls 28 and the balls 28 are prevented form yielding radially by the seal ring 14. The plug 12 is confined between the uphole slanted ledge 24a and support ring 26 with the downhole slanted ledge 24b.

In figure 2b pressure have been applied on the uphole side of the plug 12. A force greater than the shear value of the shear element 16 and the biasing force of the biasing member 18 combined have acted on the uphole seal ring piston area 14a and forced the seal ring 14 in a downhole direction into its first position.

In figure 2c the pressure on the uphole side of the plug 12 is bleed down. The biasing member 18 will via the biasing rod 32 push the seal ring 14 in an uphole direction into its second position. The balls 28 have now lost radial support and can yield radially outwards.

In figure 2d pressure is again applied on the uphole side of the plug 12. The plug 12 will be move downwards against the support ring 26. The support ring 26 will yield in the downhole direction and the plug 12 will be pushed against one or more breaking members 20, in this case one or more breaking pins.

In figure 2e the plug is shattered and the through channel 3 is open.

In a third possible embodiment the plug breaking mechanism 10 showed in fig. 3a-f the plug breaking mechanism 10 is equipped with a ratchet c-ring 36a and a ratchet lock ring 36b. The housing 2 is equipped with a downhole slanted ledge 24b. The plug 12 is limited to slide axially between the uphole slanted ledge 24a and the downhole slanted ledge 24b.

The seal ring 14 comprises both a uphole seal ring piston area 14a and a downhole seal ring piston area 14b. Where the downhole seal ring piston area 14b is exposed to the pressure in the through bore below the plug 12, through the downhole fluid ports 30b.

The breaking members 20 is for the third embodiment one or more breaking pins or edges connected to the seal ring 14 below the plug 12. The breaking member is concealed by the housing 2 with the seal ring 14 in the starting position and in the first position.

With reference to fig. 3a-d the sequence for breaking the plug will be explained.

In figure 3a the seal ring 14 is in its starting position with the shear element 16 intact and the breaking member 20 is concealed below the downhole slanted ledge 24b.

In figure 3b pressure is applied above the plug 12 and the shear element 16 is broken, the seal ring 14 is in the first position and the biasing member 18 in this case a spring is further compressed.

In figure 3c pressure is bleed down above the plug 12, the seal ring 14 is pushed upwards into the second position by the biasing member 18. In this position one or more breaking members 20 are exposed. The ratchet C-ring 36a engages the ratchet lock ring 36b and prevents the seal ring 14 with the breaking member 20 from being moved in the downhole direction.

In figure 3d pressure is again applied on the uphole side of the plug 12. The plug 12 will then be forced against one or more breaking members 20 and will shatter.

In the third possible embodiment of the invention the plug 12 can be shattered either uni-directional or bi-directional.

Fig 3a-f shows the plug breaking mechanism in a unidirectional design. The plug 12 can not be broken without applying pressure above the plug after the seal ring is in the second position. The breaking member 20 won't reach the plug 12 when the plug 12 is resting against the uphole slanted ledge 24a.

Figure 3g and h the geometry is slightly changed to accommodate for bi-directional breaking of the plug 12. Now the plug 12 can be broken both by underbalance and overbalance.

Figure 3g shows how the plug 12 is shattered by underbalance. In this case the tubing above the plug 12 can be displaced to a lighter fluid, and a pressure test can be performed. The pressure test will break the shear element 16. When bleeding down the pressure after the pressure test the well will be in underbalance thus the pressure is higher below the plug 12 than above the plug 12. The pressure will act on the downhole seal ring piston area 14b, through the downhole fluid port 30b, and push the seal ring 14 in the uphole direction and forcing the breaking member 20 against the plug 12, shattering the plug 12.

In case the underbalance is not sufficient pressure can be applied above the plug 12 to break the plug 12 as seen in figure 3h.

The relative size of the uphole and downhole seal ring piston areas 14a, 14b can be changed to facilitate for underbalanced shattering of the plug. The strength of the biasing member hence the biasing force can also be adapted to well conditions.

In a fourth possible embodiment (Fig 4a-e) the plug breaking mechanism 10 comprises the seal ring 14, a break ring 46 and a lock ring 44. The break ring 46 is equipped with the breaking members 20 that can protrude the seal ring 14 axially for shattering the plug 12. The lock ring 44 is shown in its entirety in figure 6 and the seal ring 14 and the breaking ring 46 is showed together in cross section in figure 9.

The lock rings 44 purpose is to keep the seal ring 14 and the break ring 46 apart and thereby preventing the breaking members 20 from protruding so deep into the seal ring 14 that it get in contact with the plug 12. The lock ring 44 keeps the break ring 46 and the seal ring 14 apart until the lock ring 44 snaps out in an internal upset 40 in the housing 2 when the seal ring 14 is in the second position. The plug is confined axially between the uphole slanted ledge 24a and a downhole slanted ledge 24b. The downhole slanted ledge 24 b is in this case placed on the seal ring 14.

With reference to fig. 4a-e the sequence for breaking the plug will be explained.

In figure 4a the seal ring 14 is in its starting position with the shear element 16 intact and the breaking member 20 is concealed below the downhole slanted ledge 24b. The relative position between the seal ring 14 and the breaking ring 46 is maintained by the lock ring 44.

In figure 4b pressure is applied above the plug 12 and the shear element 16 is broken, the seal ring 14 is in the first position and the biasing member 18 in this case a spring is further compressed.

In figure 4c pressure is bleed down above the plug 12. The seal ring 14 is pushed in the uphole direction into the second position by the biasing member 18.

In figure 4d the lock ring 44 snaps into the internal upset 40 in the housing 2, freeing the seal ring 14 to move relative to the break ring 46 thereby exposing the breaking member 20 to the plug 12.

In figure 4d pressure is again applied to above the plug. The seal ring 14 and the plug moves in the downhole direction. Breaking member 20 protrudes out through the downhole slanted ledge 24b. The plug 12 is forced against the breaking member 20 and shatters.

In a fifth possible embodiment (Fig 5a-e) the plug breaking mechanism 10 is similar to the third and the fourth embodiment. As in the fourth embodiment the plug breaking mechanism 10 comprises a lock ring 44`. The lock ring 44` in the fifth embodiment has a slightly different cross section compare to the lock ring 44 in the fourth embodiment. The lock ring 44` prevents the seal ring 14 from sliding in the downhole direction after the seal ring 14 have been in the second position. The

breaking member 20 is in this embodiment part of the seal ring 14, or connected to the seal ring 14, so that it moved with the seal ring 14.

With reference to fig. 5a-d the sequence for breaking the plug will be explained.

In figure 5a the seal ring 14 is in its starting position with the shear element 16 intact and the one or more breaking members 20 is concealed below a downhole slanted ledge 24b in the housing 2 which restricts the plug 12 from further downhole movement.

In figure 5b pressure is applied above the plug 12 and the one or more shear elements 16 is broken and the seal ring 14 is moved downhole into its first position further compressing the biasing member 18.

In figure 5c pressure is bleed down above the plug 12, the biasing member 18 have moved the seal ring 14 into its second position, exposing the breaking member 20. The lock ring 44 have snapped radially out in the internal upset 40 in the housing 2. Due to the geometry of the lock ring 44, the internal upset 40 and the seal ring 14, the seal ring 14 will be restricted from moving downhole again.

In figure 5d pressure is again applied on the uphole side of the plug 12, forcing the plug downhole against the breaking member 20, shattering the plug 12.

In figure 5e it is showed how the plug 12 can be broken with underbalance. The through bore above the plug 12 is displaced to a lighter fluid and pressure tested. The shear element is broken during the pressure test. As the pressure is bleed down after the pressure test the biasing member together with the pressure difference across the plug forces the seal ring 14 with the breaking member 20 in the uphole direction. The plug 12 will stop against the uphole slanted ledge 24a, and the breaking member 20 will be forced against the plug 12 shattering the plug 12.

If underbalance is not sufficient pressure can be reapplied above the plug 12 to force the plug 12 against the now exposed breaking member 20, to shatter the plug, as seen in figure 5f.

The relative size of the uphole and downhole seal ring piston areas 14a, 14b can be changed to facilitate for underbalanced shattering of the plug. The strength of the biasing member hence the biasing force can also be adapted to well conditions.

In all embodiments the housing 2 can be made up of a top sub and a bottom sub. The top sub and the bottom sub can be screwed together.

In some of the embodiments the seal ring 14 can be made up of two separate rings that are screwed together.

Claims

1. A plug breaking mechanism (10) for breaking a plug (12) that is sealing of a through bore (3) in a well tool device (1), comprising:

- a plug (12) disposed inside a housing (2) and axially slidable within a limited interval inside the housing (2),

- a seal ring (14) inside the housing (2) between the plug (12) and the housing (14), where it can slide axially between a first position and a second position and seals between the plug (12) and the housing (2), the seal ring (14) comprises a seal ring uphole piston area (14a) exposed to the pressure above the plug (12),

- one or more shear elements (16) with a given shear value preventing axial movement of the seal ring (14) inside the housing (2) prior to shearing the shear element (16),

- one or more biasing members (18) acting on said seal ring (14) in an uphole direction,

- one or more breaking members (20) physically separated from the plug (12) with the seal ring (14) in its first position and exposed to the plug (12) with the seal ring (14) in its second position.

2. Plug breaking mechanism (10) according to claim 1, wherein the one or more shear elements (16) is one or more shear pins.

3. Plug breaking mechanism (10) according to claim 1, wherein the seal ring (14) comprises at least one housing seal (22a) and at least one plug seal (22b).

4. Plug breaking mechanism (10) according to claim 1, wherein the biasing member (18) is a spring.

5. Plug breaking mechanism (10) according to claim 1, wherein the limited interval inside the housing (2) where the plug (12) can travel is in a starting position limited by a uphole slanted ledge (24a), and a downhole slanted ledge (24b).

6. Plug breaking mechanism (10) according to claim 1, wherein the plug (12) is made of glass.

7. Plug breaking mechanism (10) according to claim 1, wherein the biasing member (18) acts on a biasing rod (32) that can transfer the force from the biasing member (18) to push the seal ring (14) in the uphole direction.

8. Plug breaking mechanism (10) according to claim 1, wherein a downhole slanted ledge (24b) is made up by a number of tips on a number of collet fingers (34).

9. Plug breaking mechanism (10) according to claim 1, wherein the plug (12) is prevented from further downhole movement by a number of collet fingers (34) that get radial support from the seal ring (14), and after the seal ring (14) moves and the collet fingers lose radial support the plug (12) can be forced in the downhole direction against one or more breaking members (20).

10. Plug breaking mechanism (10) according to claim 1, wherein the plug breaking mechanism (10) comprises a support ring (26) with a downhole slanted ledge (24b) placed below the plug (12) in the through channel (3) and the support ring is given axially support in the downhole direction by balls (28) or segments that partly protrudes into the through channel (3) and the balls (28) or segments are prevented from yielding radially by the seal ring (14).

11. Plug breaking mechanism (10) according to claim 1, wherein the seal ring (14) comprises a seal ring downhole piston area (14b) exposed to the pressure of the through channel (3) below the plug (12).

12. Plug breaking mechanism (10) according to claim 1, wherein the plug breaking mechanism (10) comprises a ratchet lock ring (36b) fixed to the housing (2) and a ratchet c-ring (36a) that moved axially with the seal ring (14).

13. Plug breaking mechanism (10) according to claim 12, wherein the ratchet lock ring (36b) and the ratchet c-ring (36a) is locked together when the seal ring (14) is in the second position.

14. Plug breaking mechanism (10) according to claim 1, wherein the plug breaking mechanism (10) comprises a breaking ring (46) placed below the seal ring (14), with breaking members (20) that protrudes axially into the seal ring (14).

Fig 1a

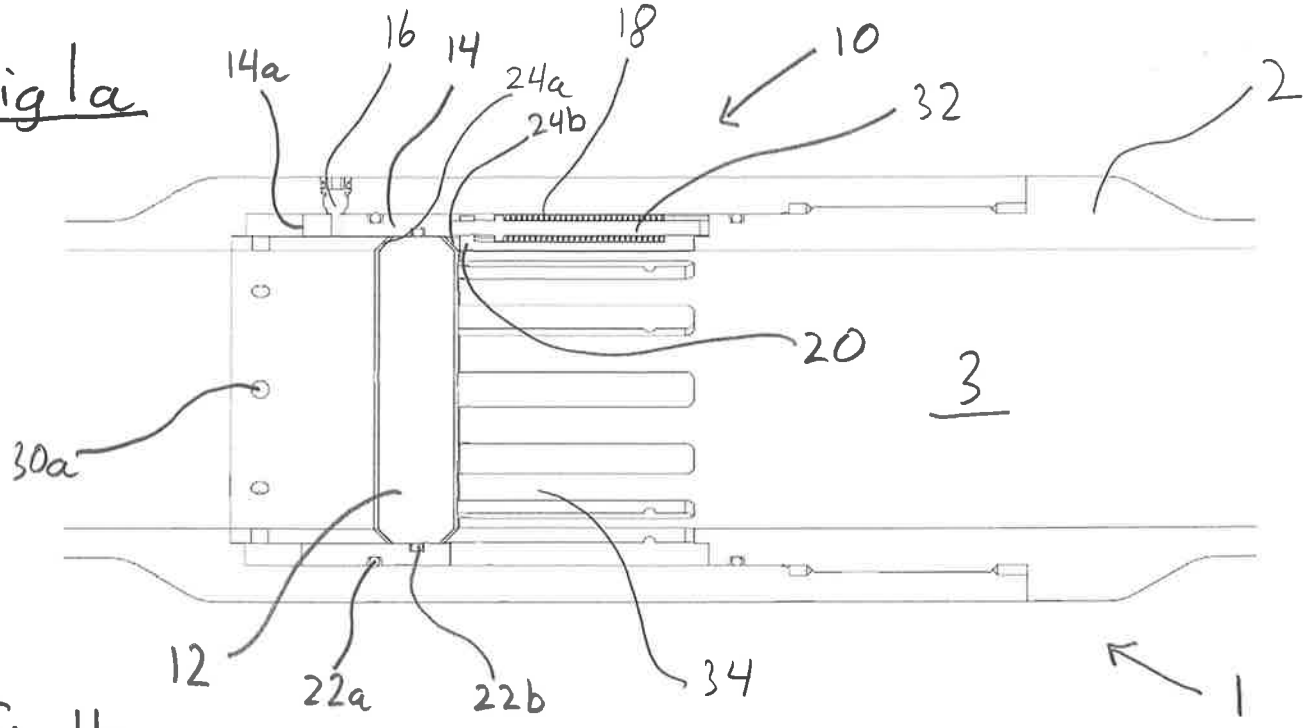


Fig 1b

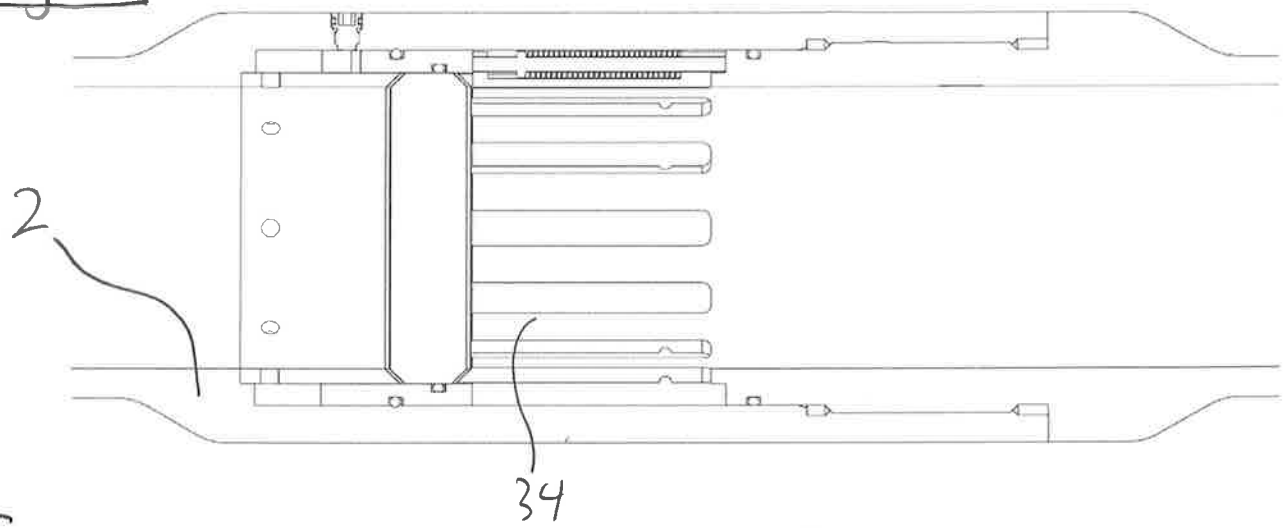


Fig 1c

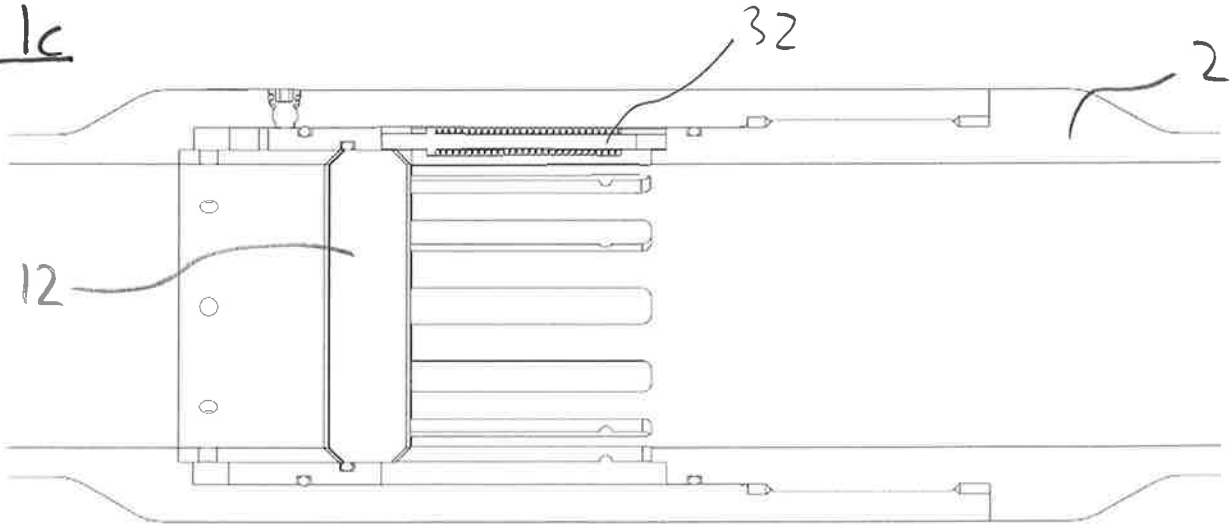


Fig 1d

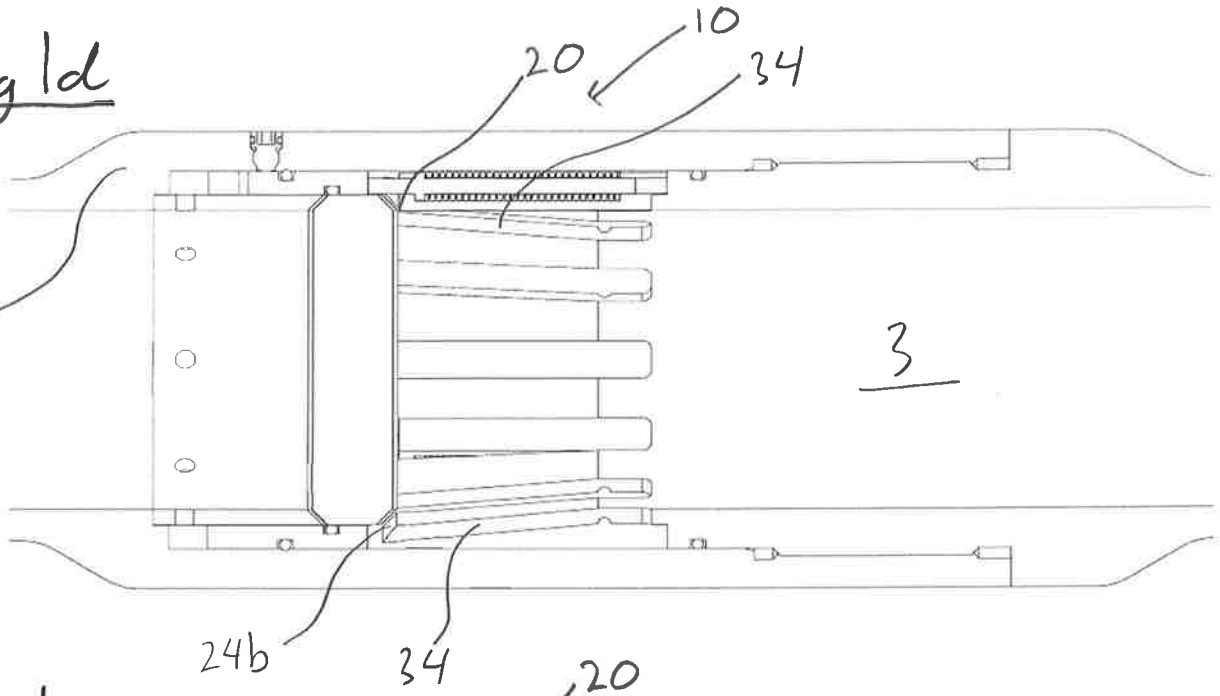


Fig 1e

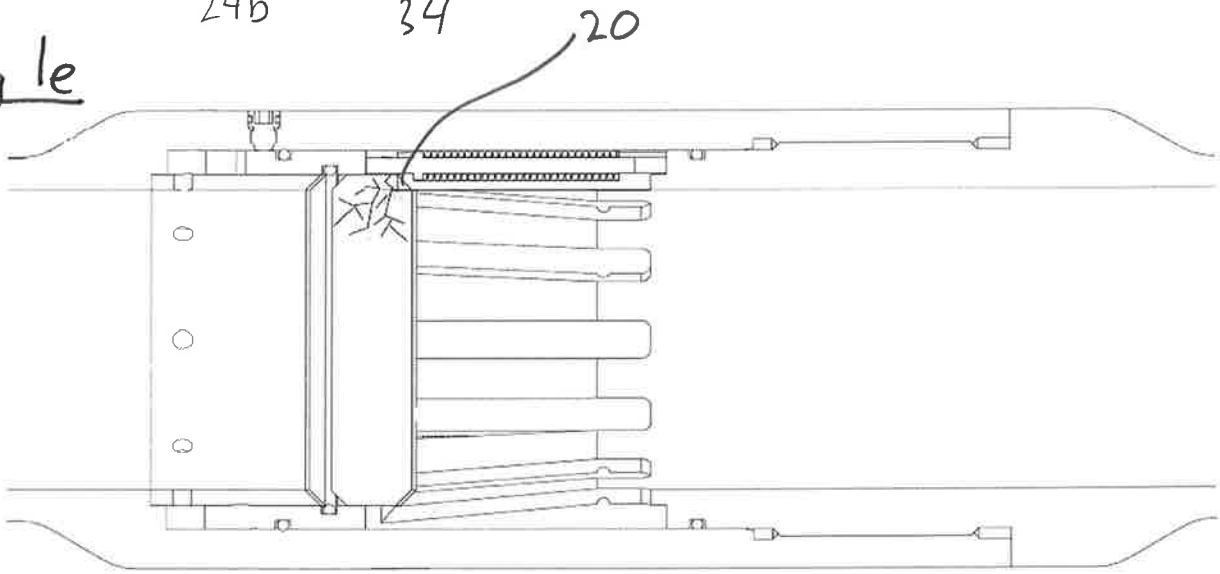


Fig 1f

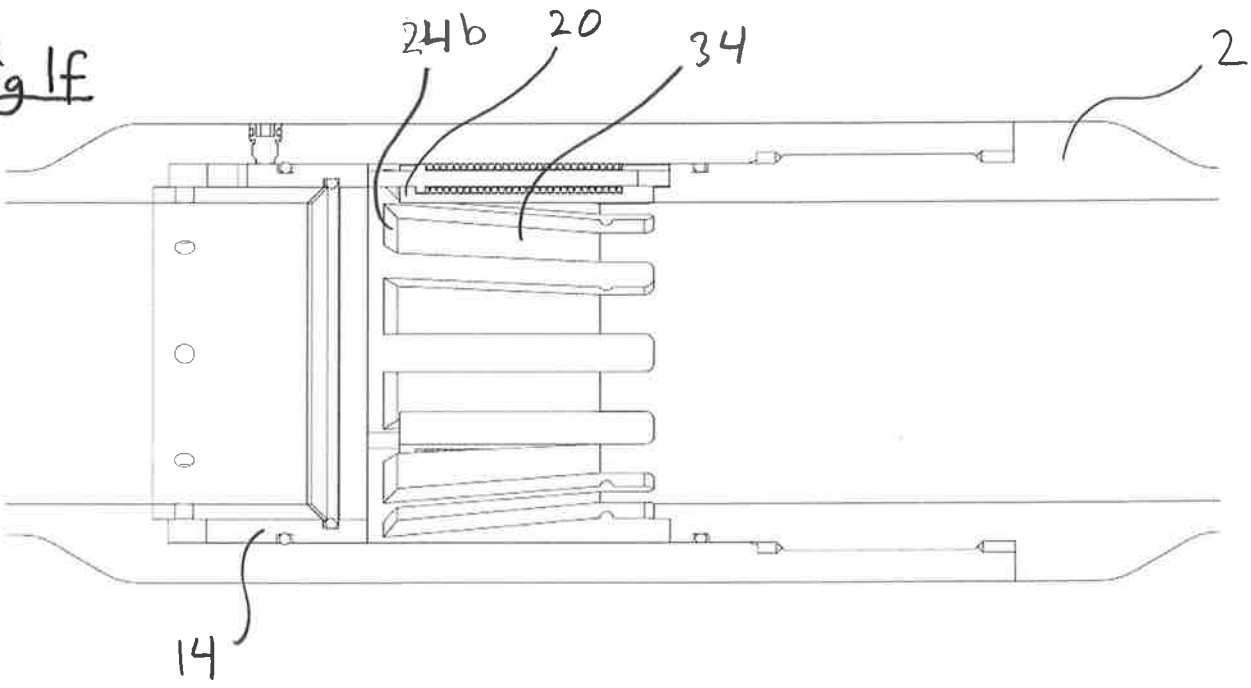


Fig 2a

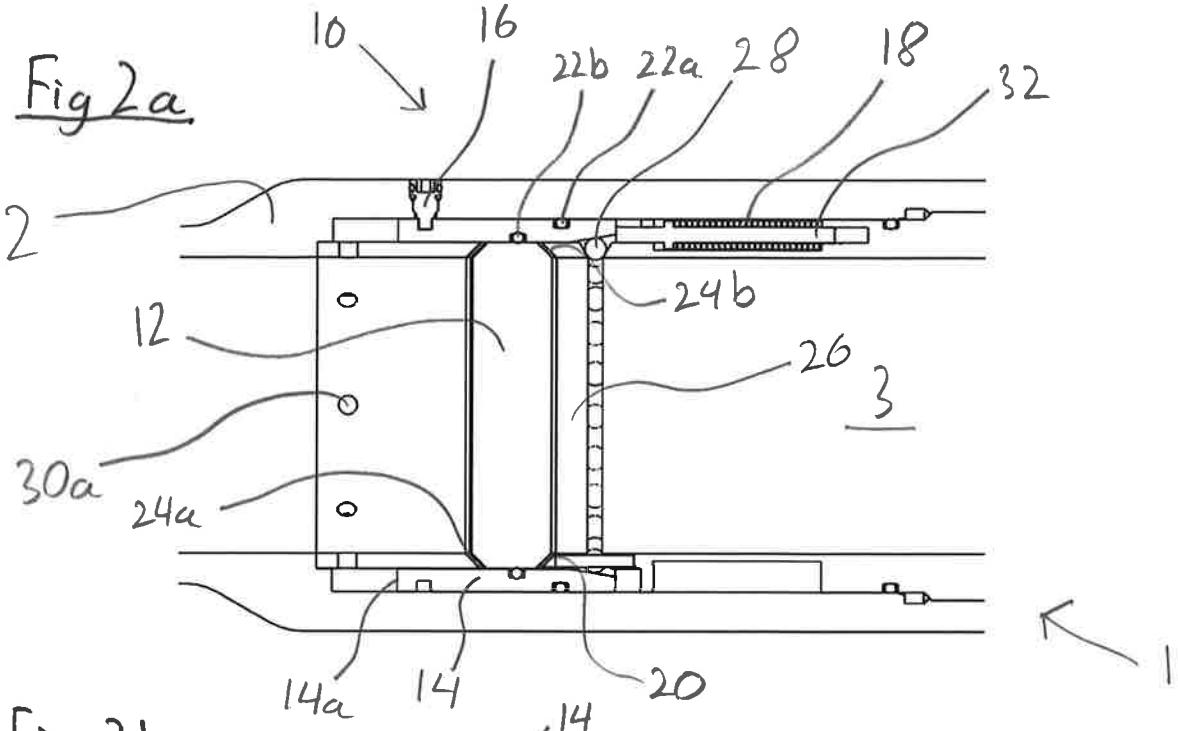


Fig 2b

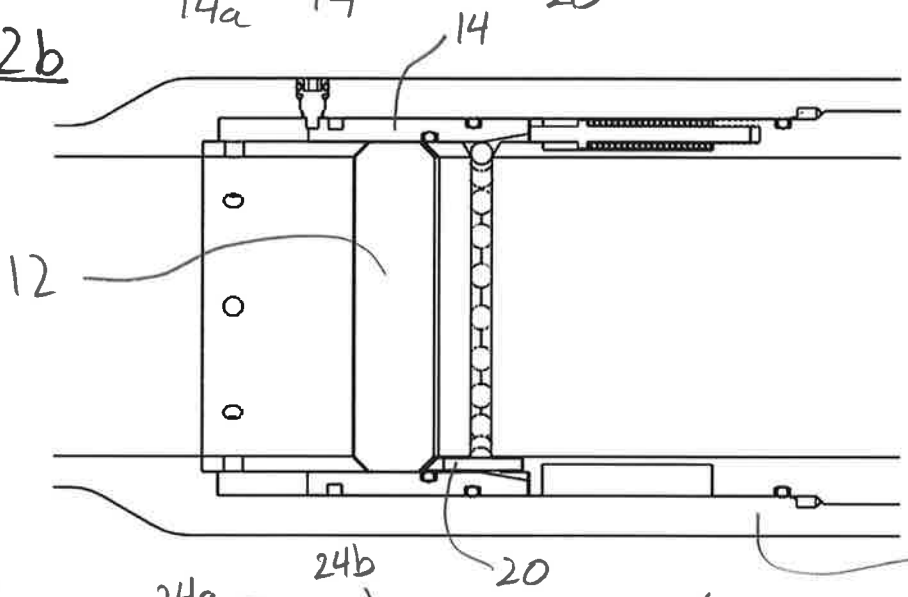


Fig 2c

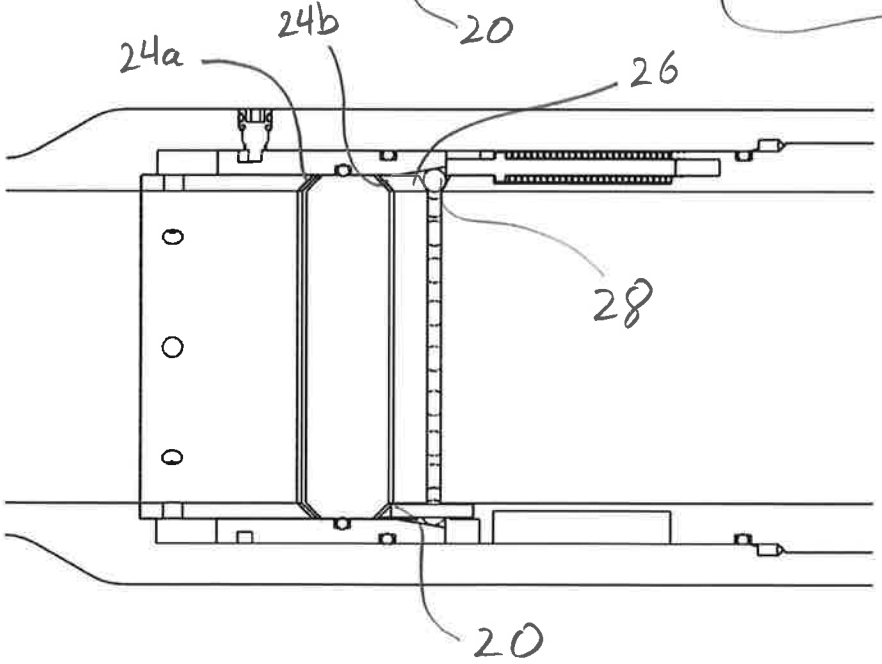


Fig 2d

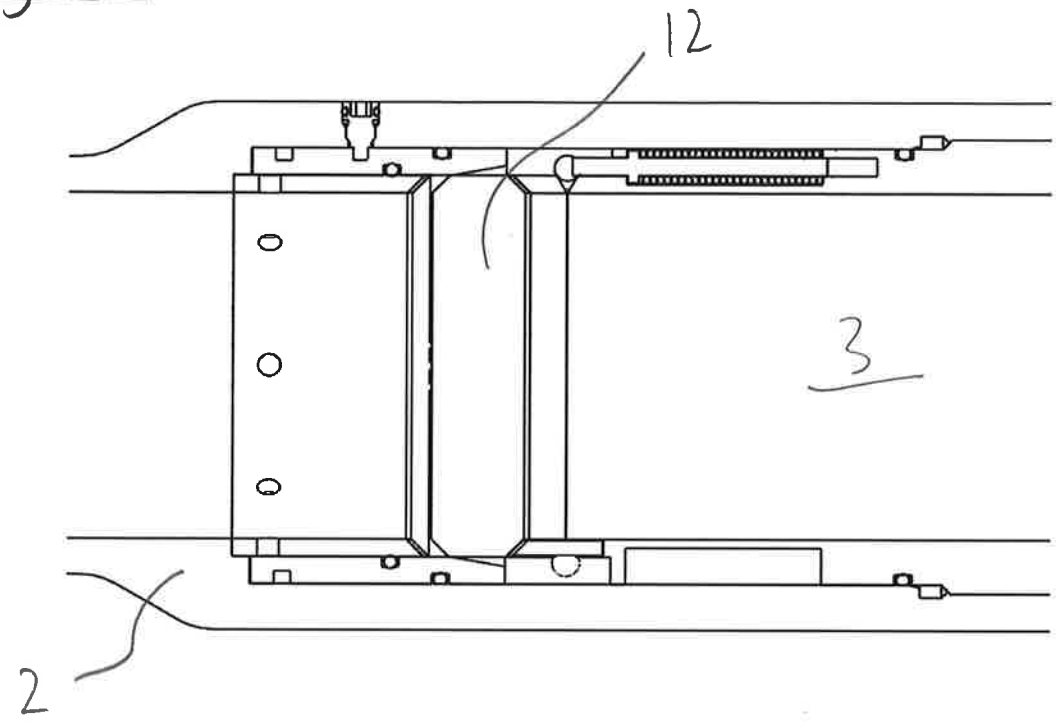


Fig 2e

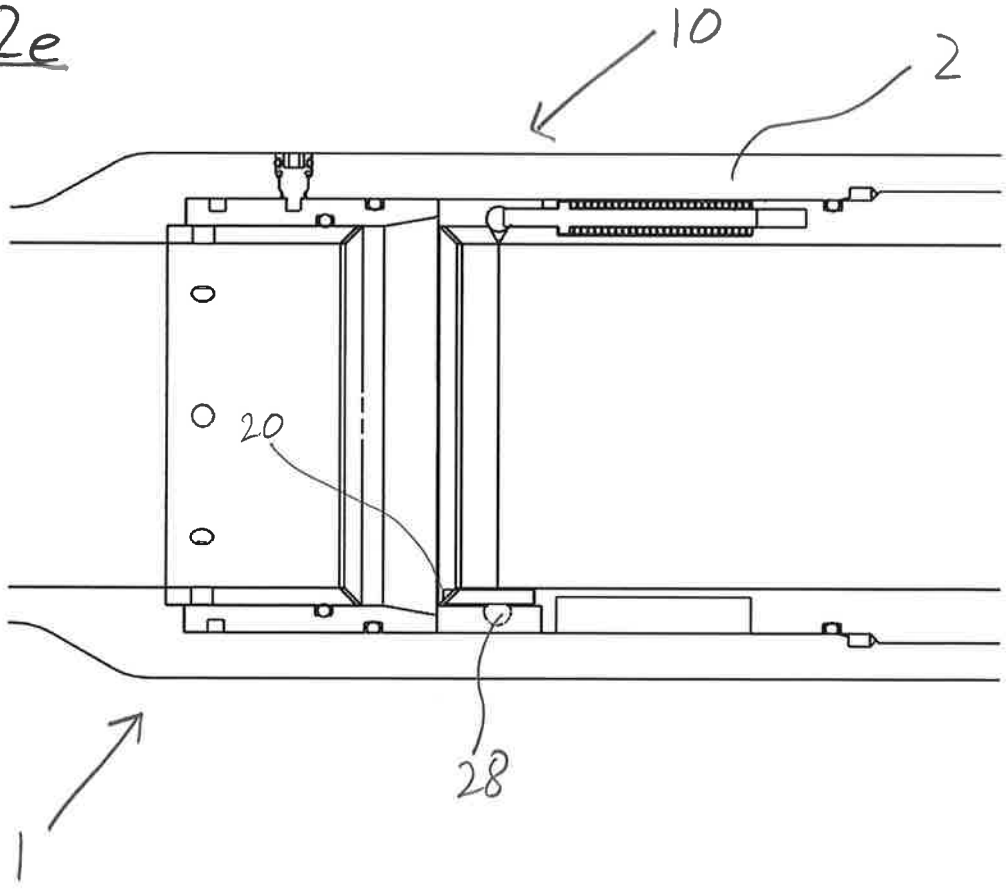


Fig 3a

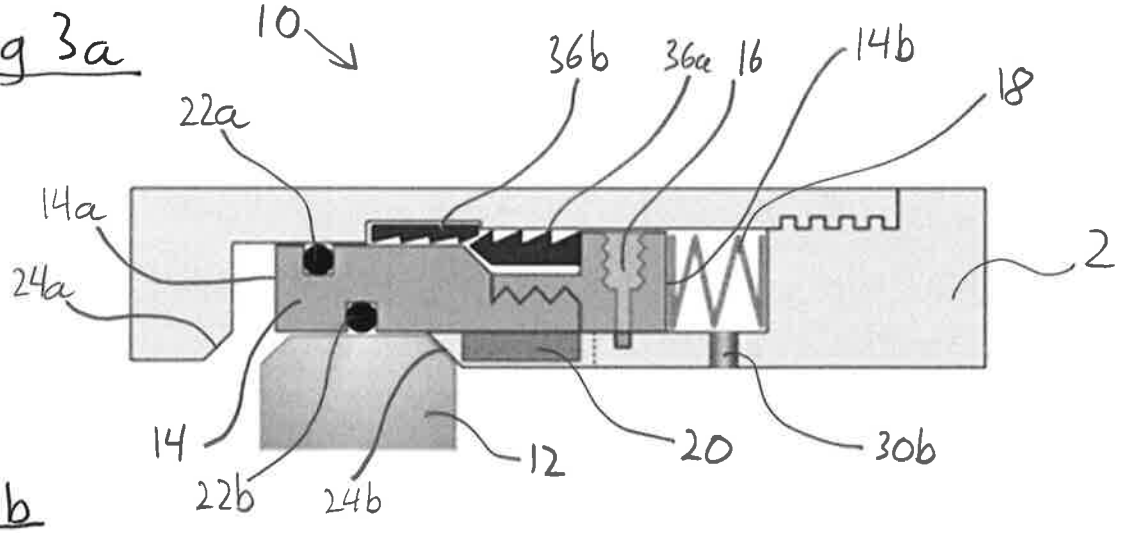


Fig 3b

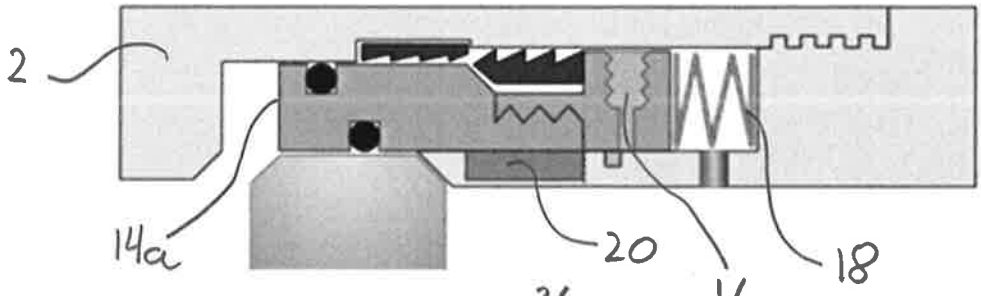


Fig 3c

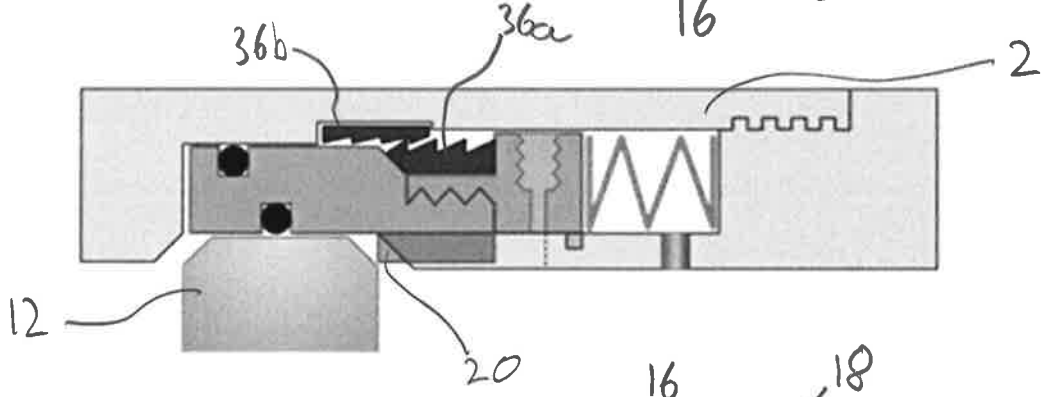


Fig 3d

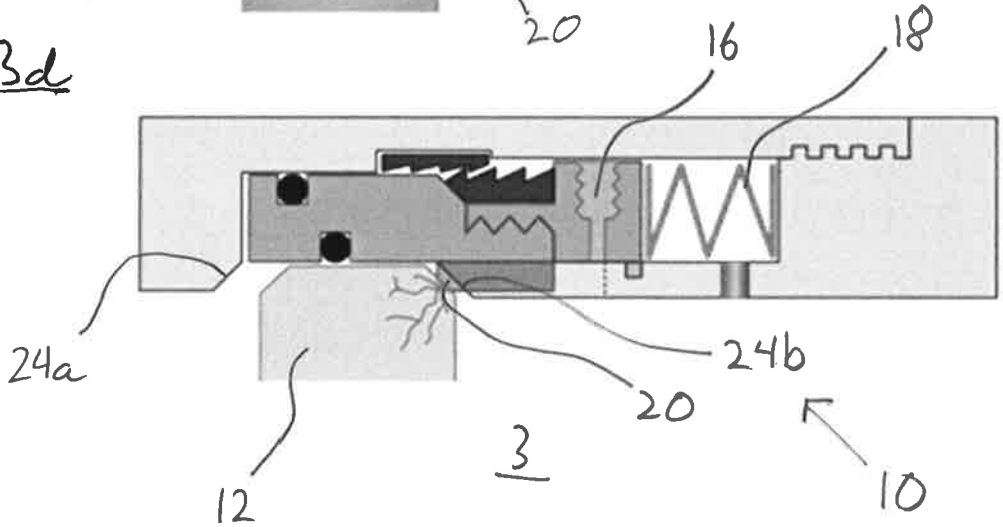


Fig 3e

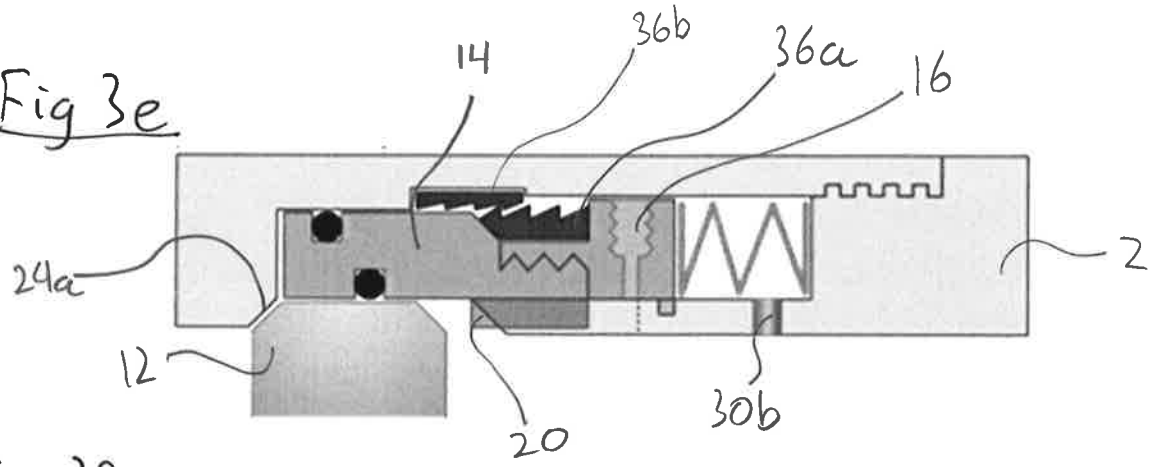


Fig 3f

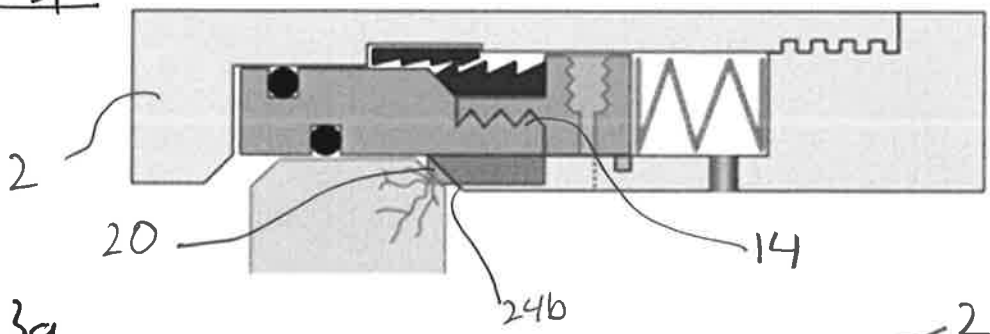


Fig 3g

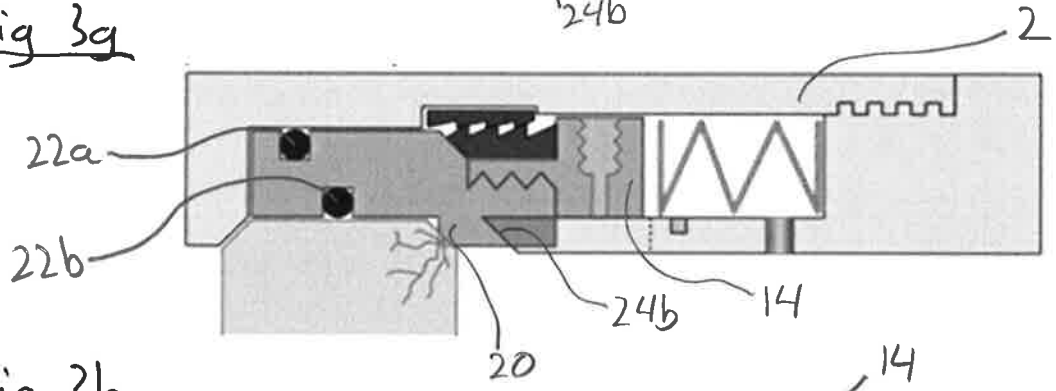


Fig 3h

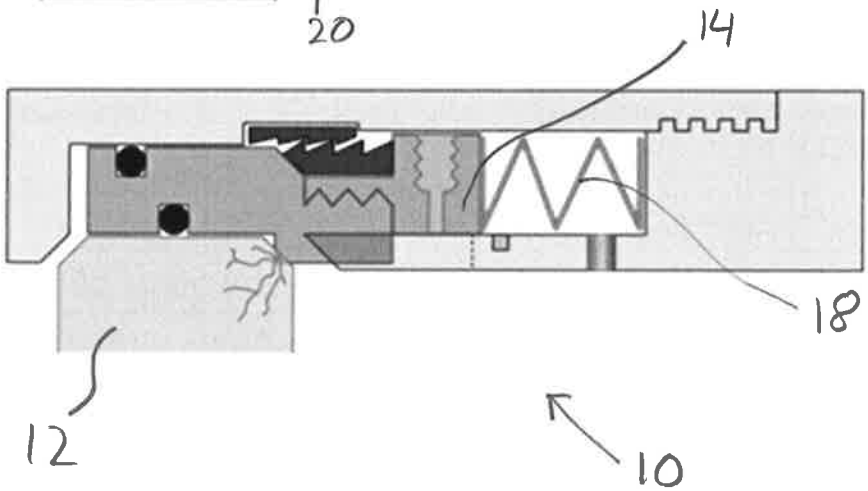


Fig 4a

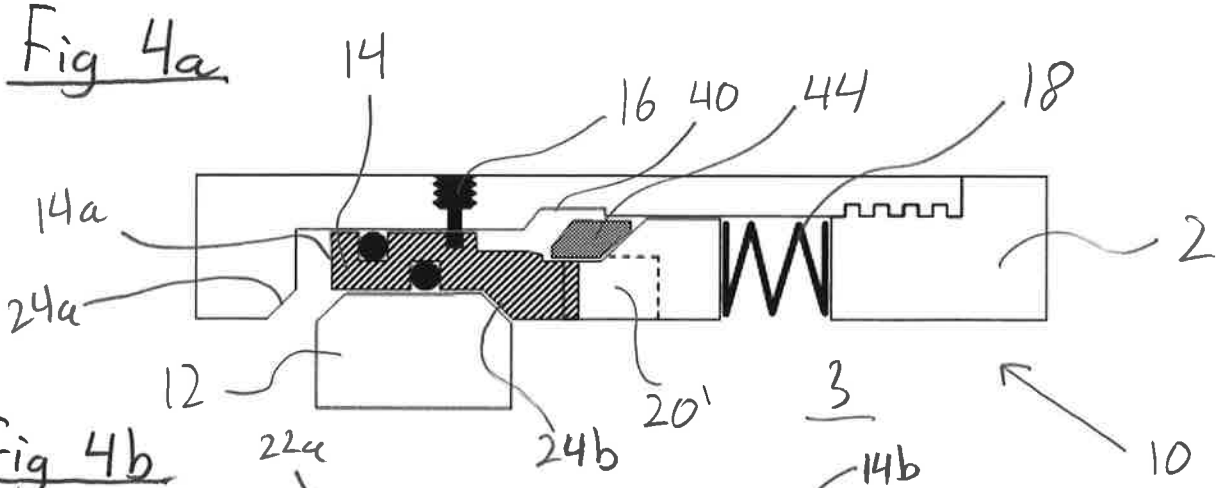


Fig 4b

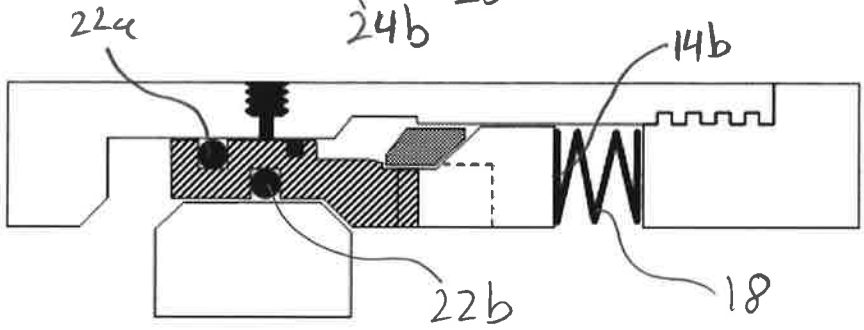


Fig 4c

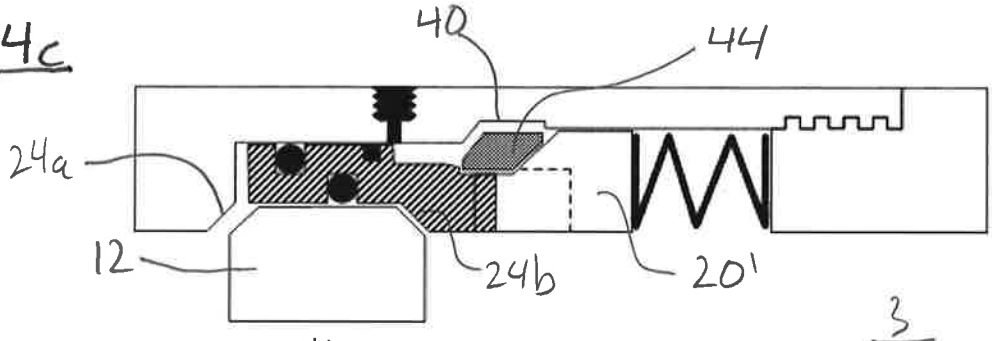


Fig 4d

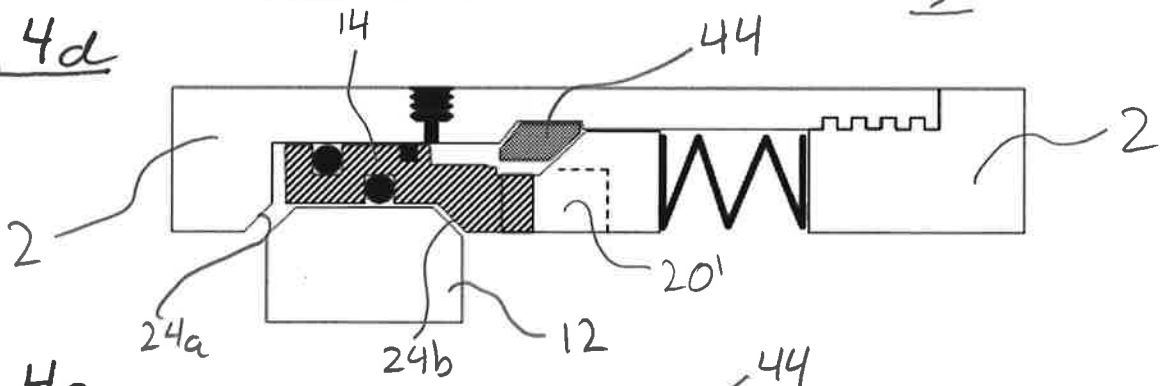


Fig 4e

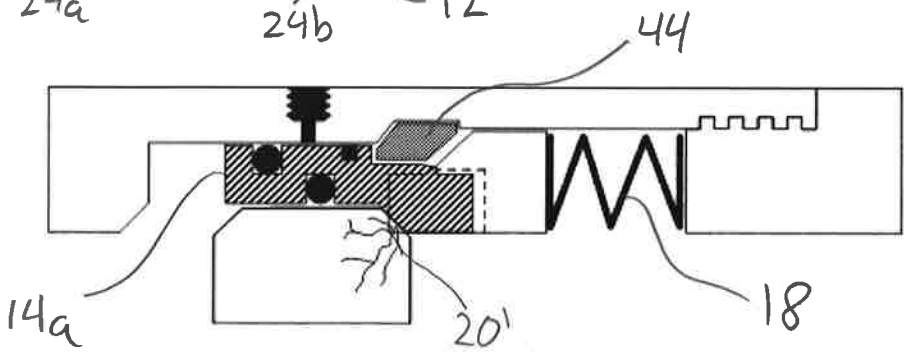


Fig 5a

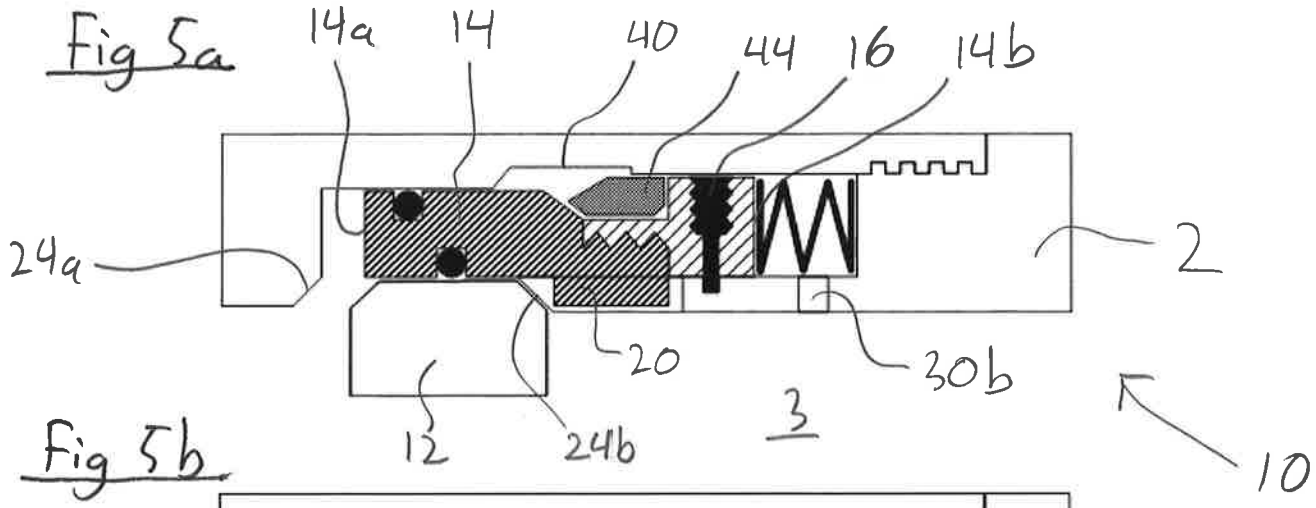


Fig 5b

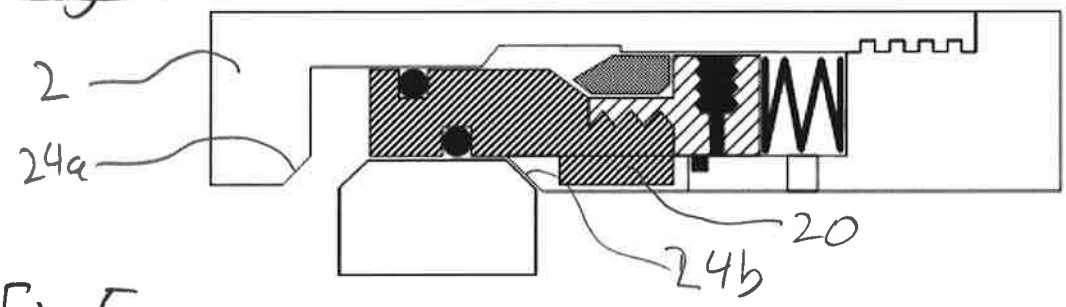


Fig 5c

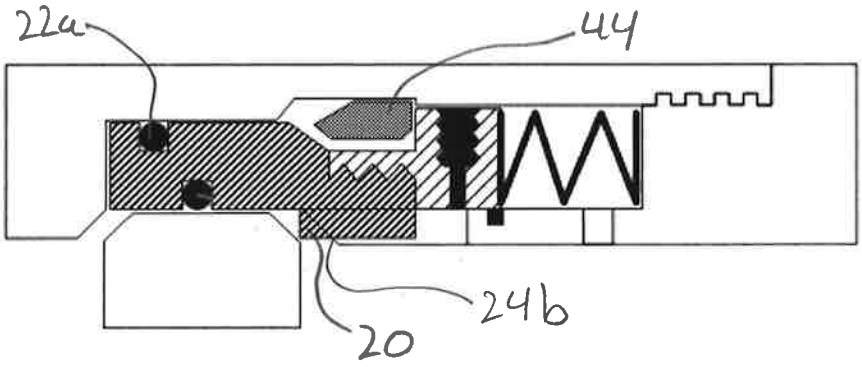


Fig 5d

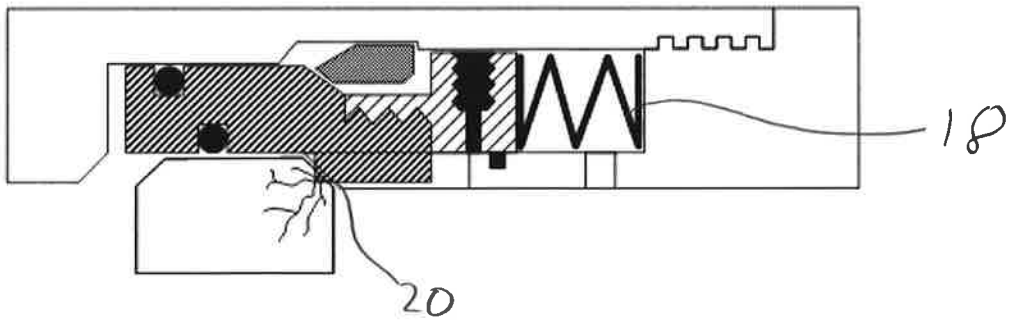


Fig 5e

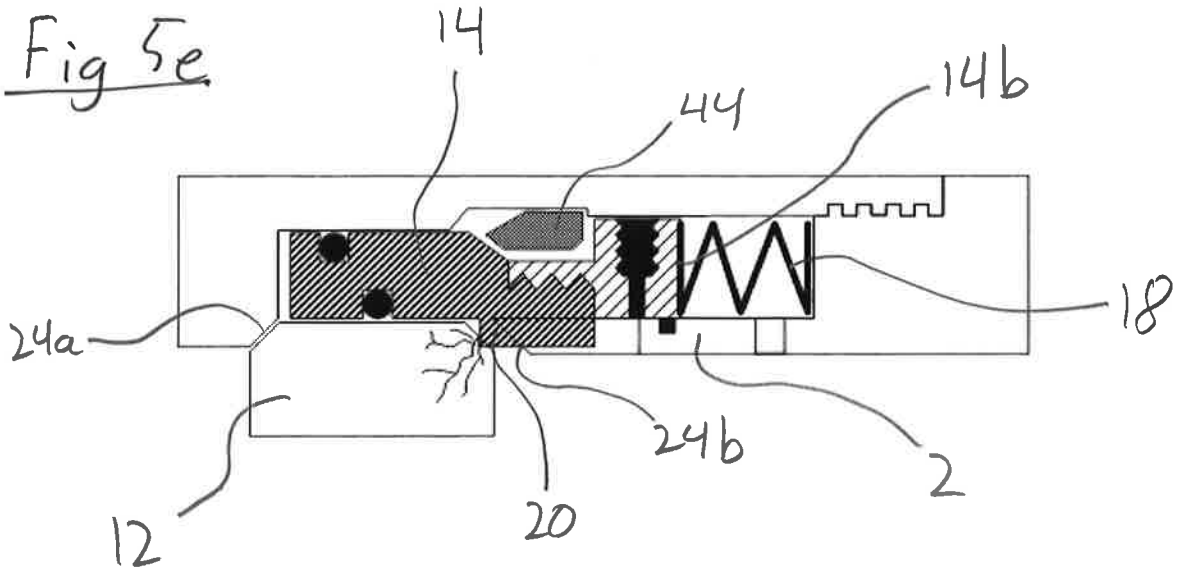


Fig 5f

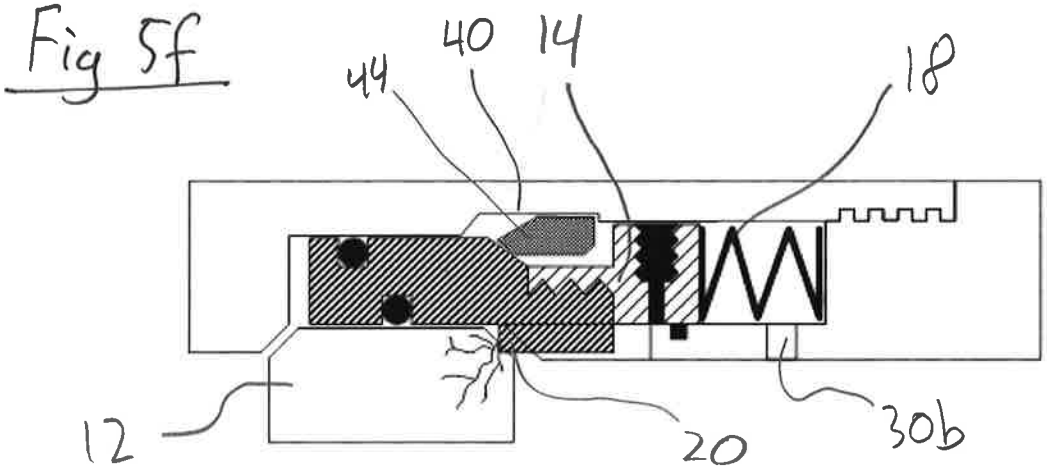


Fig 6

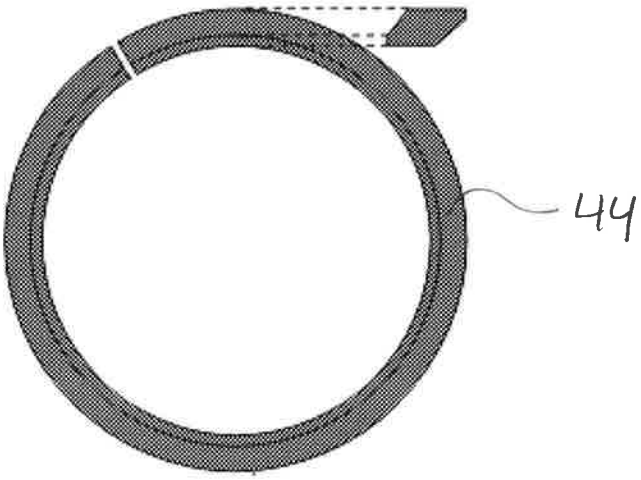


Fig 7a

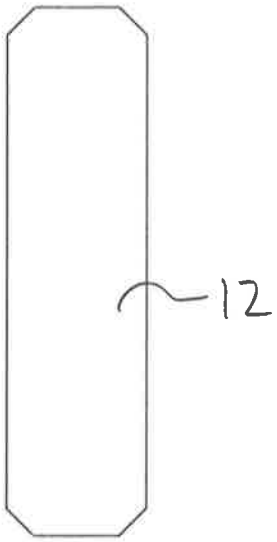


Fig 7b

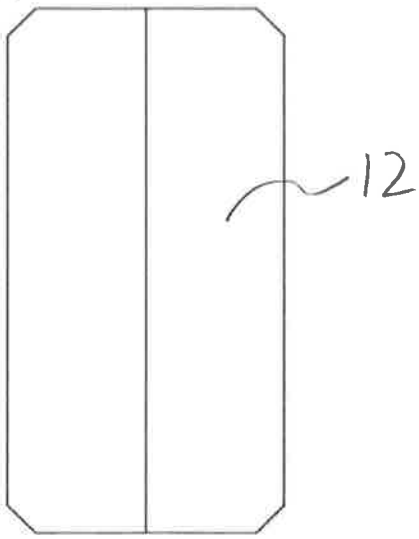


Fig 8a

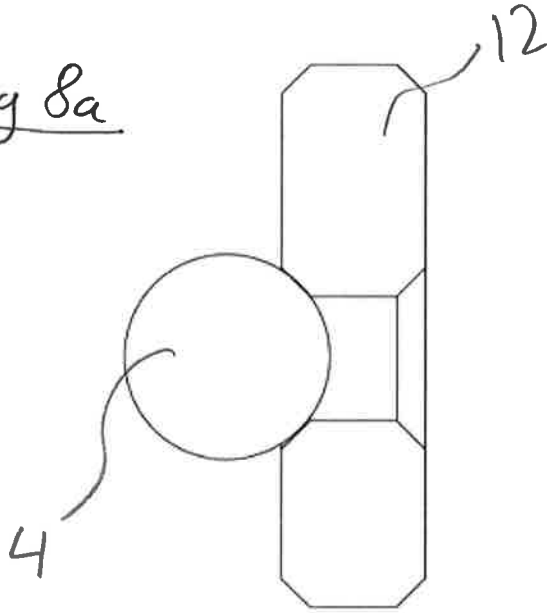


Fig 8b

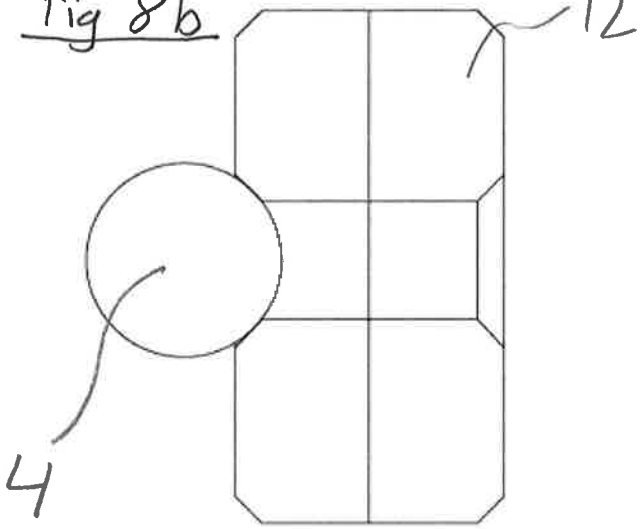


Fig 9