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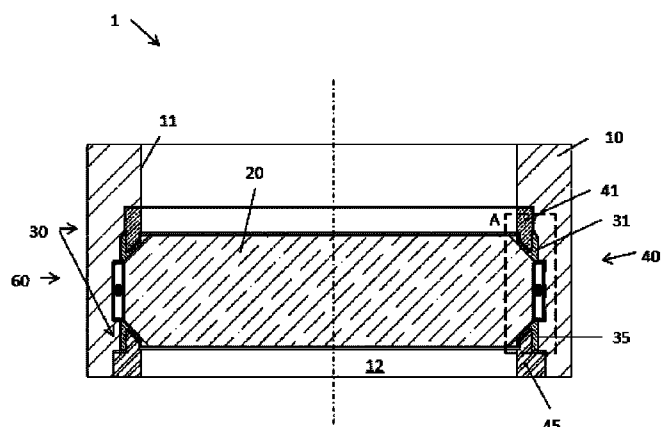
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(54) Title **Well tool device with metallic contact rings**

(56) References
Cited:
US 2012/0125631 A1
US 2007163776 A1
WO 2014148914 A2
US 2002136904 A1

(57) Abstract

The present invention relates to a well tool device (1). A housing (10) has an inner surface (11) defining a through bore (12). A frangible disc (20) comprising upper and lower chamfered supporting surfaces (20a, 20b) and is supported by a seat (40) in relation to the housing (10). A force transmitting device (30) provided is between the frangible disc (20) and the seat (40). The force transmitting device (30) is comprising an upper contact ring (31) provided between the upper chamfered supporting surface (20a) of the frangible disc (20) and the seat (40) and a lower contact ring (35) provided between the lower chamfered supporting surface (20b) of the frangible disc (20) and the seat (40).



FIELD OF THE INVENTION

The present invention relates to a well tool device with a frangible disc.

BACKGROUND OF THE INVENTION

5 Frangible well plugs are commonly used in tools for oil and/or gas wells. These plugs provide a pressure barrier in the tool, for example during periodic or permanent isolation of zones in the well, during well integrity testing, etc.

10 These frangible well plugs have a frangible barrier element in the form of a frangible disc made from glass, hardened glass, ceramics etc. The barrier element is provided in a seat in a metal housing. The barrier element may be removed by means of various techniques, where the purpose is to disintegrate the element into small pieces.

15 An example of a glass plug is known from NO 321 976 (TCO AS). The plug comprises a number of layered or stratified ring discs of a given thickness, which are placed in abutment on top of one another. Between the different layers of the plug an intermediate film of plastic, felt or paper is inserted; the various glass layers may also be joined by means of lamination by an adhesive such as a glue. During use the plug will be mounted in a plug-receiving chamber in a tubing, where the underside of the plug rests in a seat at the bottom of the chamber. An explosive charge is furthermore incorporated in the top of the plug by one or more recesses being drilled out from the top of the plug, in which recesses the explosive charge(s) are placed.

20 Another example is known from NO 20130427 (Vosstech AS). Here, the plug has one glass disc, which may be disintegrated by a radial pin or loading device being pushed into the glass disc.

One object of the invention is to provide a well plug with one glass disc body at higher pressure ratings.

25 With the above prior art well plugs, different types of seals are used between the metal and the glass. Often, one type of seal (typically o-ring) is used circumferentially around the glass disc to avoid fluid flow in the area between the glass disc and the metal housing. A second type of seal is used in the upper part and lower part of the seat to avoid contact between the glass disc and the metal housing, as is it known for the skilled person that such contact will cause an undesired breaking of the glass disc when the differential fluid pressure is increasing above a certain level. This second type of seal is often referred to as a force transmitting device, for transmitting the force applied to the glass by the fluid pressure further to the housing.

30 At high differential pressures above the glass disc, a relatively high force is applied by this fluid pressure onto the glass disc, where this relatively high force is transmitted to the seat of the housing. At such high pressures, the glass disc itself may be deformed slightly, increasing the risk for contact between the glass and the metal. Another object of the

invention is to provide a force transmitting device which increases the possible differential pressure over the glass disc.

US 2012/0125631 describes a bridge plug arrangement including a plug having an upper end and a bottom end. The bridge plug arrangement also optionally includes a cylindrical seat. The bridge plug arrangement further includes a tubular member. The tubular member may be part of a casing string. The tubular member is configured to receive the plug and, when used, the seat. The plug and/or the seat may be fabricated from a frangible material. The plug and/or seat may be optionally broken into a plurality of pieces through use of a downward mechanical force.

WO 2014/148914 describes a plug comprising at least two discrete glass discs, wherein there is provided between the glass discs a liquid which contributes to load uptake and load distribution, and a pin-/claw device is arranged to be pressed in a radial direction into at least one of the glass discs.

US 2002/0136904 describes a frangible rupture disk and mounting apparatus for use in blocking fluid flow, generally in a fluid conducting conduit such as a well casing, a well tubing string or other conduits within subterranean boreholes. The disk can also be utilized in above-surface pipes or tanks where temporary and controllable fluid blockage is required. The frangible rupture disk is made from a pre-stressed glass with controllable rupture properties wherein the strength distribution has a standard deviation less than approximately 5% from the mean strength. The frangible rupture disk has controllable operating pressures and rupture pressures.

Today, a very high precision is necessary for the chamfered surfaces of the glass disc and the chamfered surfaces of the seat. The hardening process of the glass disc comprises heating and subsequent cooling of the glass disc, which may cause the glass disc to become slightly uneven. For some prior art application, it has been found necessary to polish the surfaces of the glass disc, a process which may damage the glass disc. Hence, one object of the invention is to reduce the need for precision of the chamfered surfaces of the glass disc and the chamfered surfaces of the seat.

SUMMARY OF THE INVENTION

The invention is defined in the independent claims 1. Aspects of the invention are defined in the dependent claims.

DETAILED DESCRIPTION

Embodiments of the invention will now be described in detail with reference to the enclosed drawings, where:

Fig. 1 illustrates a cross sectional view of a prior art well tool device with a frangible disc;

Fig. 2 illustrates a cross sectional view of a first embodiment of the well tool device;

Fig. 3 is an enlarged view of detail A of fig. 2;

Fig. 4 illustrates an exploded cross sectional view of the frangible disc, upper and lower supporting rings and the upper and lower contact rings from the embodiment in fig. 2;

Fig. 5a illustrates an enlarged view of the respective cross sections of the upper supporting ring, the upper contact ring and the flexible element from fig. 4 when separated from each other;

5 Fig. 5b illustrates that the upper supporting ring, the upper contact ring and the flexible element are assembled;

Fig. 6 illustrates an alternative embodiment of the supporting rings and the contact rings;

Fig. 7a illustrates a cross section of a lower part of an alternative embodiment of the upper contact ring;

Fig. 7b illustrates an alternative embodiment to fig. 7a;

10 Fig. 7c illustrates a cross section of a lower part of an alternative embodiment of the upper contact ring and the upper supporting ring;

Fig. 7d illustrates an alternative to the embodiment in fig. 7c.

Fig. 8a and 8b illustrates two alternative embodiments of the well tool device.

15 First, fig. 1 will be described. The prior art well tool device 1 comprises a housing 1 with an inner surface 11 defining a through bore 12. A seat 40 is provided in the inner surface 11 of the housing, with an upper chamfered supporting surface 40a, a lower chamfered supporting surface 40b and a side surface 40c between the upper and lower chamfered supporting surfaces 40a, 40b. The side surface 40c is typically provided in an axial direction, i.e. parallel to the longitudinal axis I of the well tool device 1. Here, it should
20 be noted that the seat 40 is made in the inner surface 11 of the housing 10, i.e. it is made of the same material as the housing 10, often being a high quality steel material.

A frangible disc 20 is provided in the seat 40, and comprises upper and lower chamfered supporting surfaces 20a, 20b and an axial supporting side surface 20c, corresponding to the surfaces of the seat 40. In the present embodiment, the frangible disc 20 is made of a
25 hardened glass material.

In fig. 1, a seal, generally referred to with reference number 60, are provided radially between the frangible disc 20 and the housing 10. The seal 60, typically an o-ring, is provided around the frangible disc 20 between the surfaces 20c, 40c.

30 In addition, the well tool device 1 in fig. 1 comprises so-called contact-preventing seals or force transmitting devices 30a, 30b in fig. 1.

The housing 10 typically comprises first and second housing sections 10a, 10b connected to each other via a threaded connection indicated by the dashed line 14 in fig. 1. This is necessary for the assembly of the well tool device 1. First, the seals 30a, 30b, 60 and disc 20 are inserted into the first housing section 10a, then the second housing section 10b is
35 connected to the first housing section 10a, thereby locking the seals and disc to the housing 10.

It should be noted that the term "upper" is used herein to describe the side of the well tool device 1 being closest to the topside of the well, while the term "lower" is used to

describe the side of the well tool device 1 being closest to the bottom of the well, when the well tool device 1 is lowered into a oil/gas well.

It is now referred to fig. 2 and 3. Similar to fig. 1, the well tool device 1 comprises a housing 10 having an inner surface 11 defining a through bore 12, a frangible disc 20 and a seat 40. As in the prior art, the seat 40 is provided for supporting the frangible disc 20 in relation to the housing 10. There is also a sealing device generally referred to with reference number 60 provided radially between the frangible disc 20 and the seat 40.

It should be noted that the frangible disc 20 may have various shapes; the glass disc may for example be a glass object with convex surfaces.

In fig. 2 and 3, it is shown that the well tool device 1 further comprises a force transmitting device 30 provided between the frangible disc 20 and the seat 40. The force transmitting device 30 is comprising an upper contact ring 31 provided between the upper chamfered supporting surface 20a of the frangible disc 20 and the seat 40. The force transmitting device 30 is further comprising a lower contact ring 35 provided between the lower chamfered supporting surface 20b of the frangible disc 20 and the seat 40.

As mentioned in the introduction, the purpose of the force transmitting device 30 is to transmit forces applied to the glass disc 20 by fluid in the bore further from the glass disc 20 to the housing 10 via the seat 40, without breaking the glass disc 20.

The seat 40 and force transmitting device 30 will now be described with reference to fig. 4, fig. 5a and 5b.

The seat 40 comprises an upper supporting ring 41 and a lower supporting ring 45. The upper supporting ring 41 comprises a chamfered supporting surface 41a facing towards the upper chamfered supporting surface 20a of the frangible disc 20. The upper supporting ring 41 comprises a downwardly protruding element 42, where the chamfered surface 41a is provided in the lower end of the downwardly protruding element 42.

In similar way, the lower supporting ring 45 comprises a chamfered supporting surface 45a facing towards the lower chamfered supporting surface 20b of the frangible disc 20. The lower supporting ring 45 comprises an upwardly protruding element 46, where the chamfered surface 45a of the lower supporting ring 46 is provided in the upper end of the protruding element 46 of the supporting ring 46.

The upwardly and downwardly protruding elements 42, 46 are extending in the circumferential direction of the respective rings 41, 45.

It should be noted that the upper and lower supporting rings 41, 45 are not in contact with the frangible disc. The upper and lower supporting rings 41, 45 may for example be made of the same material as the housing 10, typically a steel material.

As shown in fig. 5a, a cross section of the upper supporting ring 41 is substantially "T"-shaped. Similarly, a cross section of the lower supporting ring 45 is also substantially "T"-shaped, however, the lower supporting ring 46 is turned upside down in fig. 4.

The force transmitting device 30 is comprising an upper contact ring 31 and a lower contact ring 35, as shown in fig. 4. The upper contact ring 31 is provided between the

chamfered surface 41a of the upper supporting ring 41 and the upper chamfered supporting surface 20a of the frangible disc 20. The lower contact ring 35 is provided between the chamfered surface 45a of the lower supporting ring 45 and the lower chamfered supporting surface 20b of the frangible disc 20. The contact rings 31, 35 are in contact with the frangible disc, more specifically, they are in contact with the chamfered surfaces of the frangible disc.

The upper contact ring 31 comprises a recess 32 extending in the circumferential direction of the contact ring 31 and the lower contact ring 35 comprises a corresponding recess 36 extending in the circumferential direction of the contact rings 35.

As shown in fig. 5a, a cross section of the upper contact ring 31 is substantially "U"-shaped. Accordingly, a cross section of the lower contact ring 35 is also substantially "U"-shaped.

In the preferred embodiment, the protruding element 42 of the upper supporting ring 41 and the recess 32 of the upper contact ring 31 are configured to be engaged with each other, as shown in fig. 5b. Similarly, the protruding element 46 of the lower supporting ring 45 and the recess 36 of the lower contact ring 35 are configured to be engaged with each other.

The well tool device 1 further comprises a sealing device 60 provided between the side surface 20c of the frangible disc 20 and the side surface 40c of the seat 40, as shown in fig. 3. The side surface 40c of the seat 40 may here be a side surface of the housing 10. The sealing device 60 may be an O-ring or several O-rings which is considered known for a skilled person.

It is now referred to fig. 7a. Here, the cross section of the contact rings 31, 35 are shown with chamfered surfaces 31a, 35a respectively. In this embodiment, there are no flexible elements 51, 55 and there are no supporting rings 41, 45. Preferably, the contact rings 31, 35 are provided directly in contact with the housing 10.

In fig. 7b, recesses 32, 36 are provided in the contact rings 31, 35 respectively. The recesses 32, 36 are provided in parallel with the chamfered surfaces 31a, 35a respectively. As shown in fig. 7b, flexible elements 51, 55 are provided in the recesses 32, 36 provided in the contact rings 31, 35. Accordingly, it is achieved that when a high fluid pressure is applied to the glass disc, causing the glass disc to bend slightly, the flexible ring elements 51, 55 will allow the contact rings 31, 35 to move slightly to adapt to the bended glass disc.

It is now referred to fig. 7c. Here, the flexible elements 51, 55 are glued as a layer between the contact rings 31, 35 and the supporting rings 41, 45 respectively. Again, the flexible ring elements 51, 55 will allow the contact rings 31, 35 to move slightly to adapt to the bended glass disc at high pressures.

It is now referred to fig. 7d, which is similar to fig. 7c. Here, the contact rings 51, 55 and the flexible elements 51, 55 are connected to the supporting rings 41, 45 respectively, by means of connection devices 70 such as screws, pins etc.

It is now referred to fig. 8a and 8b, which show embodiments of a well tool device 1 similar to the one shown in fig. 2. In fig. 8a the sealing device 60 comprises a sealing ring 61 with a T-shaped cross sectional shape. An upper filler material 62a is provided axially between the sealing ring 61 and the upper contact ring 31 and a lower filler material 62b are provided above and below the sealing ring 61. In fig. 8b, the sealing device 60 comprises an upper sealing ring 61a and a lower sealing ring 61b with a T-shaped cross sectional shape. As for fig. 8a, a filler material 62a, 62b, 62c is provided between the sealing rings 61a, 61b and the upper and lower contact rings 31, 35.

Preferably, the contact rings 31, 35 are made of a metal or metal alloy having an E-module equal to the E-module of the material of the frangible disc 20 plus/minus 30% of E-module of the material of the frangible disc 20. Moreover, the contact rings 31, 35 are preferably made of a metal or metal alloy having a low friction glass.

In the present embodiment, the contact rings 31, 35 are made of the material sold under the name ToughMet 3 by Materion Corporation. This material is a metal alloy comprising

- a) 14.5% - 15.5% Ni by weight;
- b) 7.5% - 8.5% Sn by weight;
- c) 76.0% - 78.0% Cu by weight;

wherein the remainder of the alloy is copper and impurities. Accordingly, the material is a copper alloy as defined by UNS C 72900.

It is now referred to fig. 4, fig. 5a and 5b. Here it is shown that a upper flexible ring element 51 is provided between the chamfered surface 41a of the upper supporting ring 41 and the recess 32 of the upper contact ring 31. Similarly, a lower flexible ring element 55 is provided between the chamfered surface 45a of the lower supporting ring 45 and the recess 36 of the lower contact ring 35.

As a high differential pressure over the frangible disc will bend the frangible disc slightly, the flexible ring elements 51, 55 will allow the contact rings 31, 35 to move slightly together with the frangible disc in relation to the supporting rings 41, 45.

As mentioned in the introduction below, it has previously not been known that a metal or metal alloy could be used in contact with such a frangible disc in a well tool device 1.

Accordingly, the present invention is also related to the use the above metal alloy as a sealing device 30 in a well tool device 1 comprising a housing 10, a frangible disc 20 and a seat 40 for supporting the frangible disc 20 in relation to the housing 10, where the sealing device 30 is provided between the frangible disc 20 and the seat 40.

It is now referred to fig. 6. Here, the protruding element 42 of the supporting rings 41 comprises a connection element 42a configured for engagement with a corresponding connection element 32a provided in the recess 32 of the contact ring 31. Similar connection elements may be provided on the lower supporting ring 46 and the lower contact ring 31. In this way the upper rings 31, 42 (and, if present, ring 51) may be connected together as one ring unit, and the lower rings (35, 45 (and, if present, ring 55) may be connected together as another ring unit, which will simplify the assembly of the well tool device 1.

The well tool device 1 according to the present invention (disclosed in fig. 2) has been tested according to ISO 14310 V0 up to 430 bar at a temperature of 121°C. Other tests show that the frangible disc 20 may be supported by the contact rings up to 830 bar at 150°C, without disintegration of the glass disc. Hence, it is shown that by selecting a proper type of metal or metal alloy, a glass material may actually be provided in contact with such a metal or metal alloy.

It should be noted that in prior art, the seat 40 is normally provided as a part of the housing 10 itself, i.e. the chamfered surfaces of the seat is provided by machining the housing parts. In the present invention, the chamfered surfaces of the seat 40 are provided as a part of the supporting rings 41, 45, which again are supported in the housing 10.

The well tool device 1 described herein may be a part of a plugging device, such as a bridge plug. The housing 10 will then typically be a part of the mandrel of the plugging device. The well tool device 1 may also be a part of a completion string, where the purpose of the frangible glass disc is used to pressure test the completion string, and when the frangible disc is removed in order to start the production from the well. The housing 10 will here typically be a part of the completion string. The well tool device 1 may also be a part of other well tools where a temporary barrier is needed.

CLAIMS

1. Well tool device (1) comprising:

- a housing (10) having an inner surface (11) defining a through bore (12);
- a frangible disc (20) comprising upper and lower chamfered supporting surfaces (20a, 20b);
- a seat (40) for supporting the frangible disc (20) in relation to the housing (10);
- a force transmitting device (30) provided between the frangible disc (20) and the seat (40);

characterized in that:

- the force transmitting device (30) is comprising an upper contact ring (31) provided between the upper chamfered supporting surface (20a) of the frangible disc (20) and the seat (40);
 - the force transmitting device (30) is comprising a lower contact ring (35) provided between the lower chamfered supporting surface (20b) of the frangible disc (20) and the seat (40);
 - the upper and lower contact rings (31, 35) are provided in contact with flexible elements (51, 55).
2. Well tool device (1) according to claim 1, where the flexible elements (51, 55) are flexible ring elements (51, 55).
3. Well tool device (1) according to claim 2, where the flexible elements (51, 55) are provided in recesses (32, 36) provided in the contact rings (31, 35).
4. Well tool device (1) according to any one of claims 1 – 3, where the seat (40) comprises:
- an upper supporting ring (41) provided between the upper contact ring (31) and the housing (10);
 - a lower supporting ring (45) provided between the lower contact ring (35) and the housing (10).
5. Well tool device (1) according to claim 4, where the flexible elements (51, 55) are provided axially between the upper and lower contact rings (31, 35) and the upper and lower supporting rings (41, 45) respectively.
6. Well tool device (1) according to claim 4 or 5, where the upper supporting ring (41) is comprising a chamfered supporting surface (41a) facing towards the upper chamfered supporting surface (20a) of the frangible disc (20) and where the lower supporting ring (45) is comprising a chamfered supporting surface (45a) facing towards the lowered chamfered supporting surface (20b) of the frangible disc (20).

7. Well tool device (1) according to claim 6, where:

- the recesses (32, 36) of the upper and lower contact rings (31, 35) are extending in the circumferential direction of the contact rings (31, 35);

5 - the chamfered surfaces (41a, 45a) of the supporting rings (41, 46) are provided in ends of respective protruding elements (42, 46) of the supporting rings (41, 46); where the protruding elements (42, 46) of the supporting rings (41, 45) are inserted into the respective recesses (32, 36) of the contact rings (31, 35).

8. Well tool device (1) according to any one of the above claims, where the contact rings (31, 35) are made of a metal or metal alloy having an E-module equal to the
10 E-module of the material of the frangible disc (20) plus/minus 30% of E-module of the material of the frangible disc (20).

9. Well tool device (1) according to any one of the above claims, where the contact rings (31, 35) are made of a metal or metal alloy, where the friction coefficient between the glass disc (20) and the metal or metal alloy is 0.1 or lower.

15 10. Well tool device (1) according to any one of the above claims, where the contact rings (31, 35) are made of an metal alloy comprising:

a) nickel 14.5% - 15.5% by weight;

b) zinc 7.5% - 8.5% by weight;

wherein the remainder of the alloy is copper and impurities.

20 11. Well tool device (1) according to claim 1, where the upper and lower contact ring (31, 35) are made of a metal or metal alloy.

PATENTKRAV

1. Brønnverktøynnretning (1) omfattende:

- 5 - et hus (10) som har en indre overflate (11) som definerer et gjennomgående hull (12),
- en knusbar skive (20) som omfatter øvre og nedre skråfasede støtteflater (20a, 20b),
- et sete (40) for understøttelse av den knusbare skiven (20) i forhold til huset (10),
- 10 - en kraftoverførende innretning (30) som er tilveiebrakt mellom den knusbare skiven (20) og setet (40),

karakterisert ved at:

- den kraftoverførende innretningen (30) omfatter en øvre kontaktring (31) som er tilveiebrakt mellom den øvre skråfasede støtteflaten (20a) til den knusbare skiven (20) og setet (40),
- 15 - den kraftoverførende innretningen (30) omfatter en nedre kontaktring (35) som er tilveiebrakt mellom den nedre skråfasede støtteflaten (20b) til den knusbare skiven (20) og setet (40),
- den øvre og nedre kontaktringen (31, 35) er tilveiebrakt i kontakt med fleksible elementer (51, 55).

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2. Brønnverktøynnretning (1) ifølge krav 1, der de fleksible elementene (51, 55) er fleksible ringelementer (51, 55).

3. Brønnverktøynnretning (1) ifølge krav 1 eller 2, der de fleksible elementene (51, 55) er tilveiebrakt i utsparinger (32, 36) som er tilveiebrakt i kontaktringene (31, 35).

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4. Brønnverktøynnretning (1) ifølge ethvert av kravene 1-3, der setet (40) omfatter:

- en øvre støttering (41) som er tilveiebrakt mellom den øvre kontaktringen (31) og huset (10),
- en nedre støttering (45) som er tilveiebrakt mellom den nedre kontaktringen (35) og huset (10).

30

5. Brønnverktøyyinnretning (1) ifølge krav 4, der de fleksible elementene (51, 55) henholdsvis er tilveiebrakt aksialt mellom den øvre og nedre kontaktringen (31, 35) og den øvre og nedre støttingen (41, 45).
6. Brønnverktøyyinnretning (1) ifølge krav 4 eller 5, der den øvre støttingen (41) omfatter en skråfaset støtteflate (41a) som vender mot den øvre skråfasede støtteflaten (20a) til den knusbare skiven (20) og der den nedre støttingen (45) omfatter en skråfaset støtteflate (45a) som vender mot den nedre skråfasede støtteflaten (20b) til den knusbare skiven (20).
7. Brønnverktøyyinnretning (1) ifølge krav 6, der:
- utsparingene (32, 36) hos den øvre og nedre kontaktringen (31, 35) strekker seg i den omkretsmessige retningen av kontaktringene (31, 35),
 - de skråfasede overflatene (41a, 45a) hos støttingene (41, 46) er tilveiebrakt i ender av respektive utstikkende elementer (42, 46) av støttingene (41, 46), der de utstikkende elementene (42, 46) av støttingene (41, 45) er innsatt i de respektive utsparingene (32, 36) hos kontaktringene (31, 35).
8. Brønnverktøyyinnretning (1) ifølge ethvert av kravene ovenfor, der kontaktringene (31, 35) er laget av et metall eller metallegering som har en E-modul som er lik E-modulen til materialet til den knusbare skiven (20) pluss/minus 30 % av E-modulen til materialet i den knusbare skiven (20).
9. Brønnverktøyyinnretning (1) ifølge ethvert av kravene ovenfor, der kontaktringene (31, 35) er laget av et metall eller en metallegering, der friksjonskoeffisienten mellom glasskiven (20) og metallet eller metallegeringen er 0,1 eller lavere.
10. Brønnverktøyyinnretning (1) ifølge ethvert av kravene ovenfor, der kontaktringene (31, 35) er laget av en metallegering som omfatter:
- a) nikkel 14,5 vekt% - 15,5 vekt%,
 - b) sink 7,5 vekt% - 8,5 vekt%,
- der resten av legeringen er kobber og urenheter.
11. Brønnverktøyyinnretning (1) ifølge krav 1, der den øvre og nedre kontaktringen (31, 35) er laget av et metall eller metallegering.

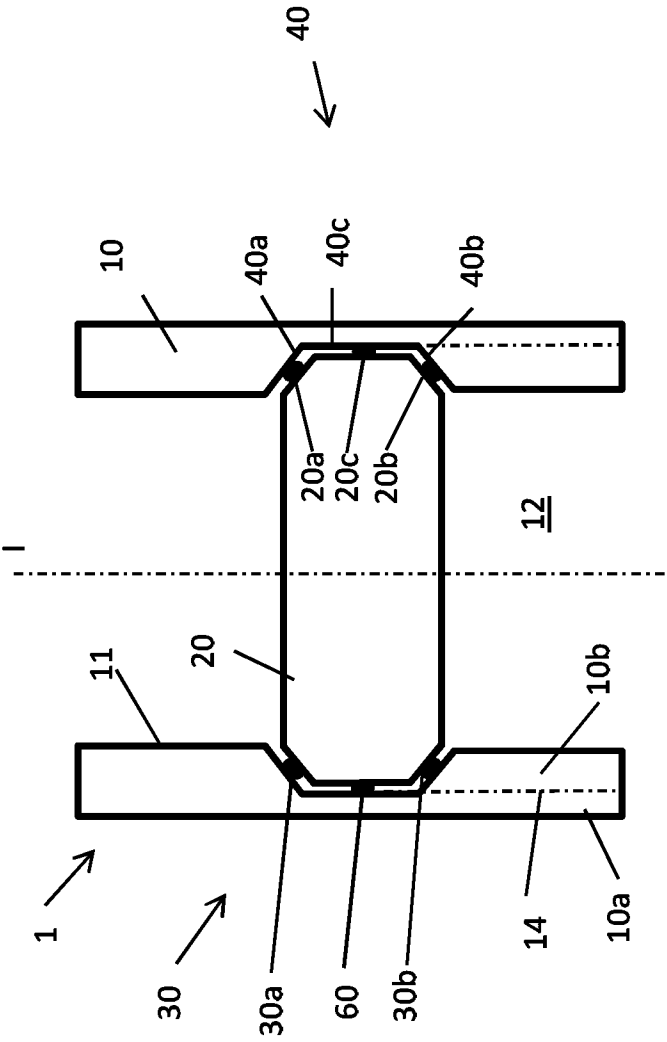


Fig. 1: Prior art

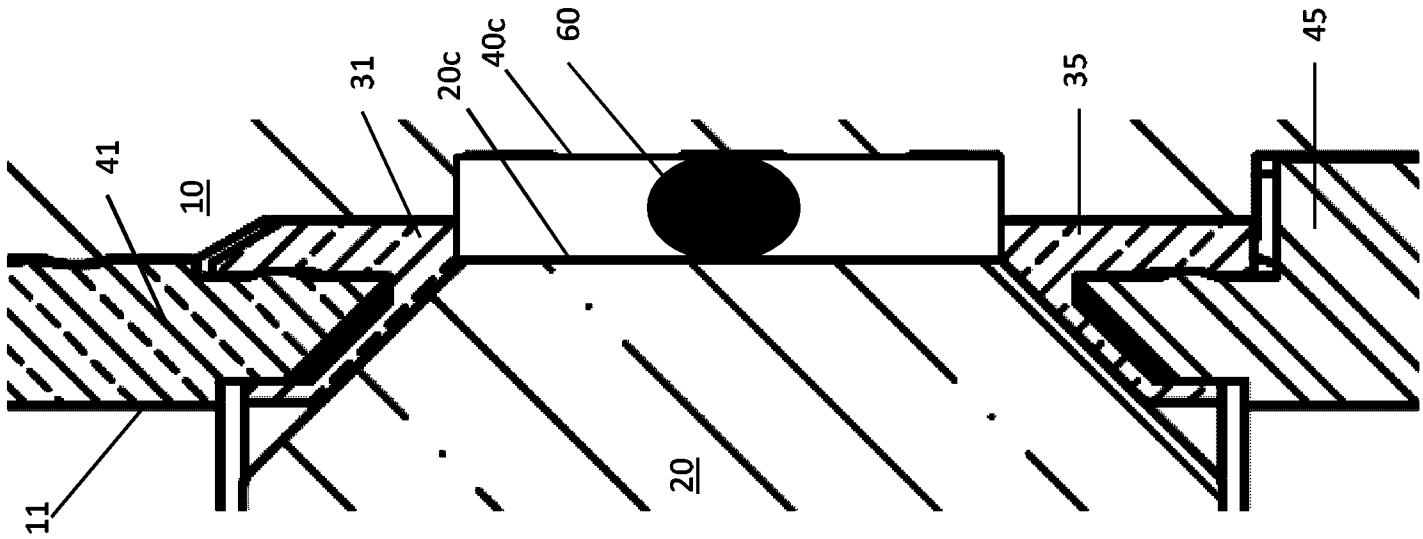


Fig. 3

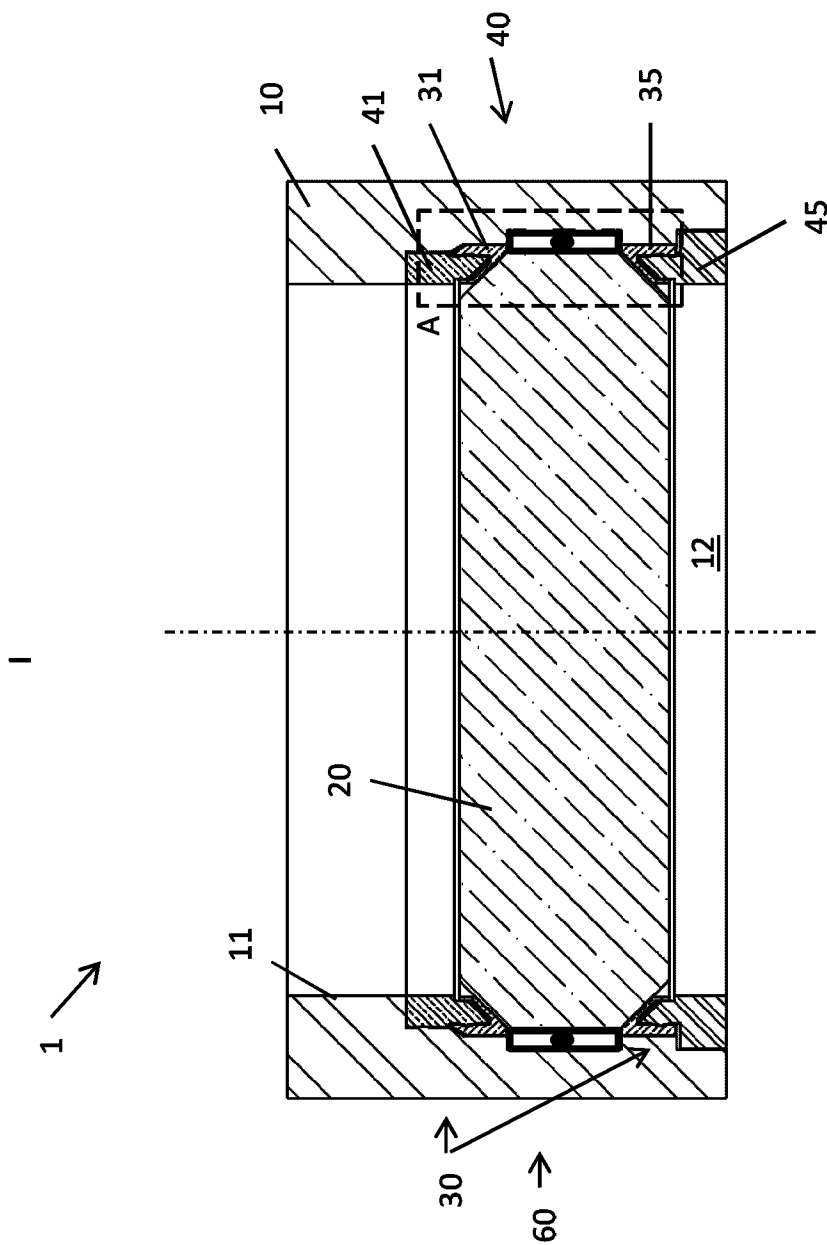


Fig. 2

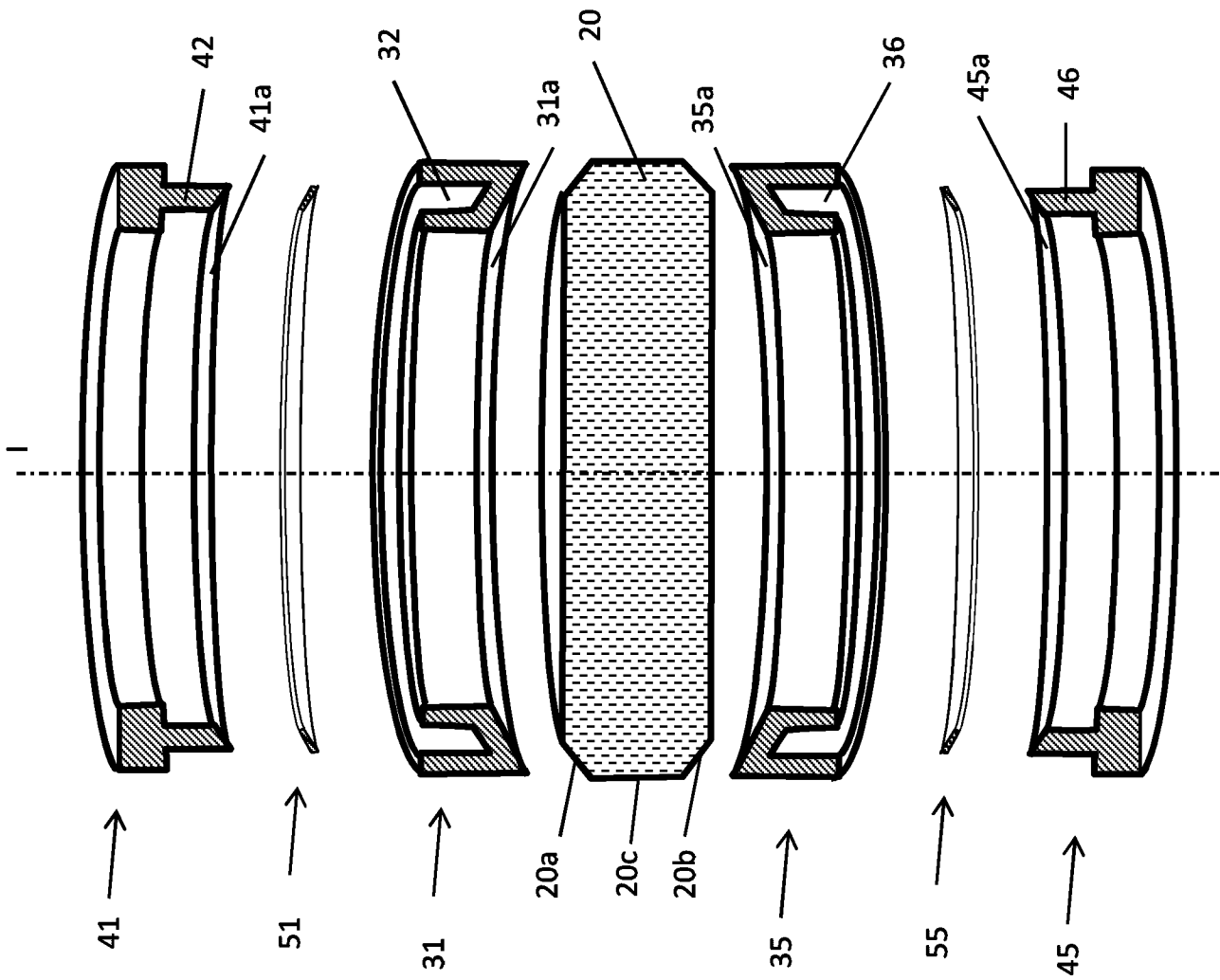


Fig. 4

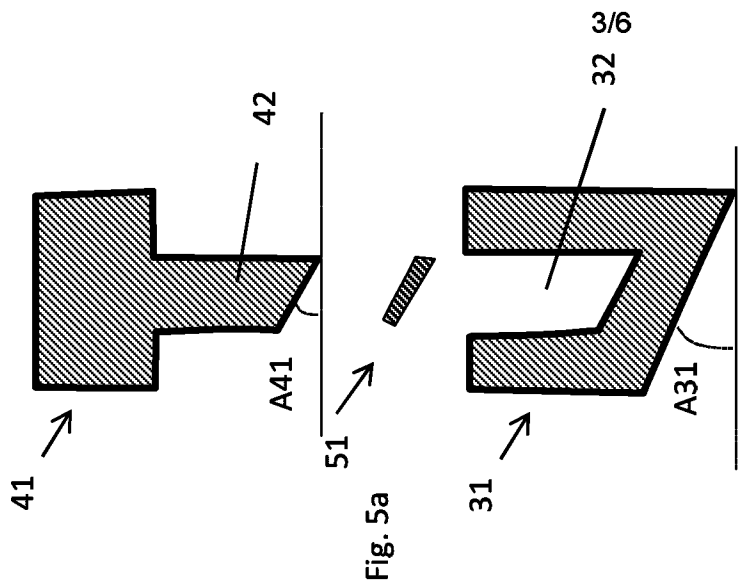


Fig. 5a

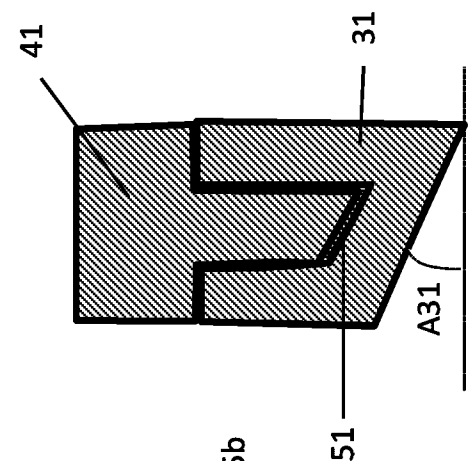


Fig. 5b

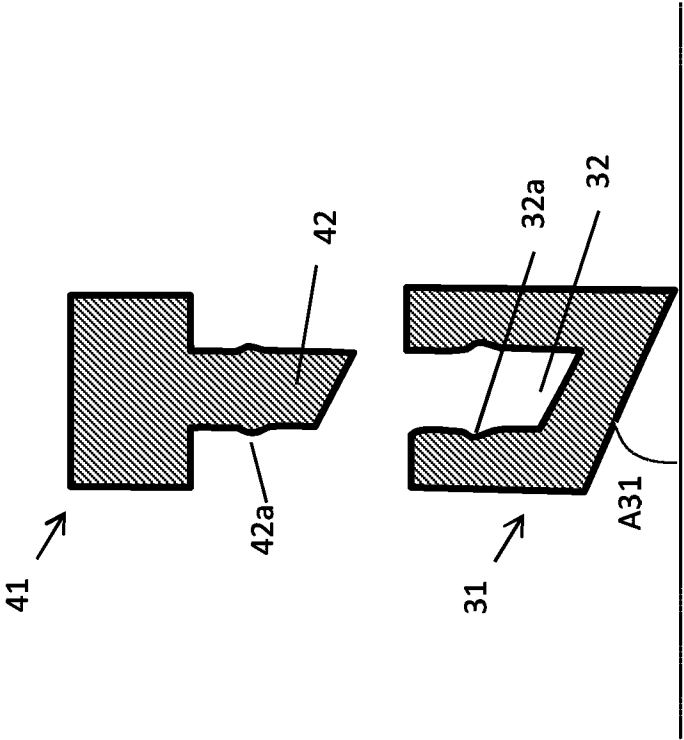


Fig. 6

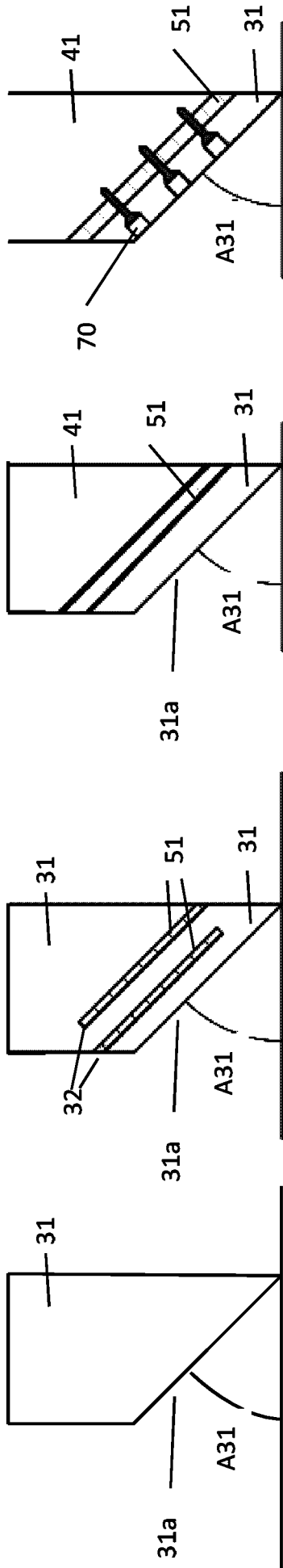


Fig. 7a

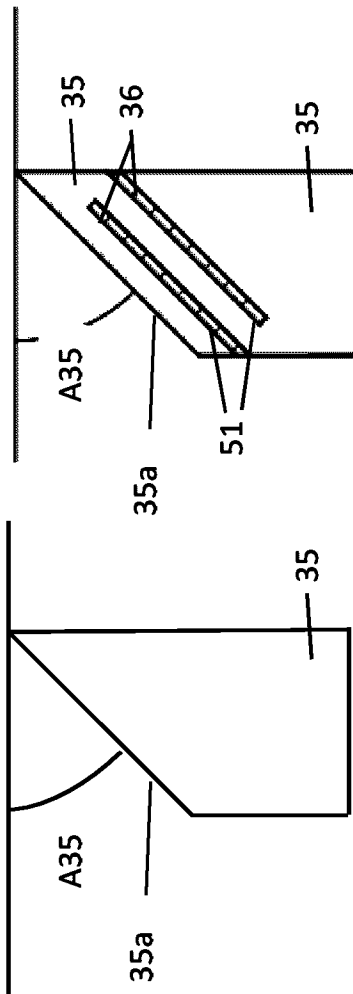


Fig. 7b

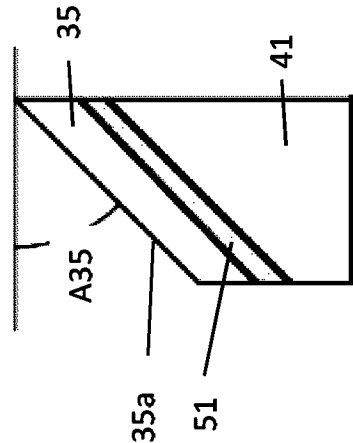


Fig. 7c

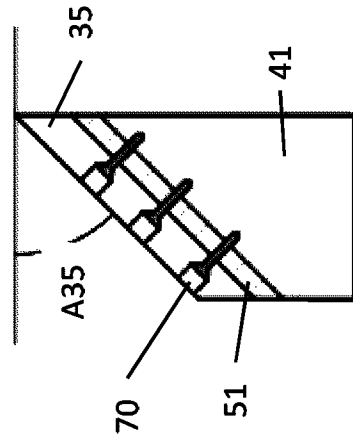


Fig. 7d

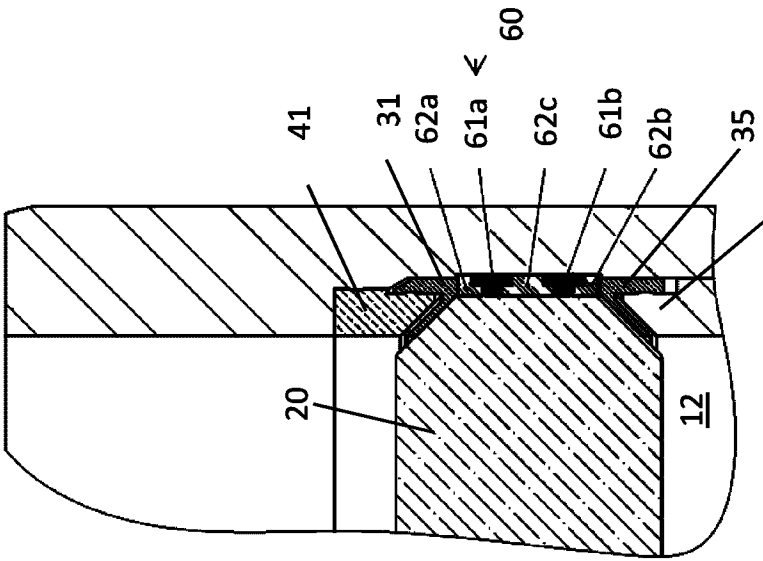


Fig. 8b

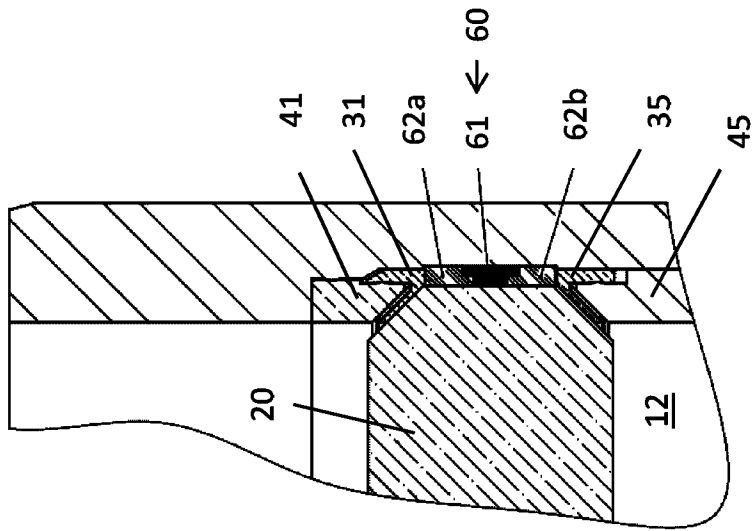


Fig. 8a