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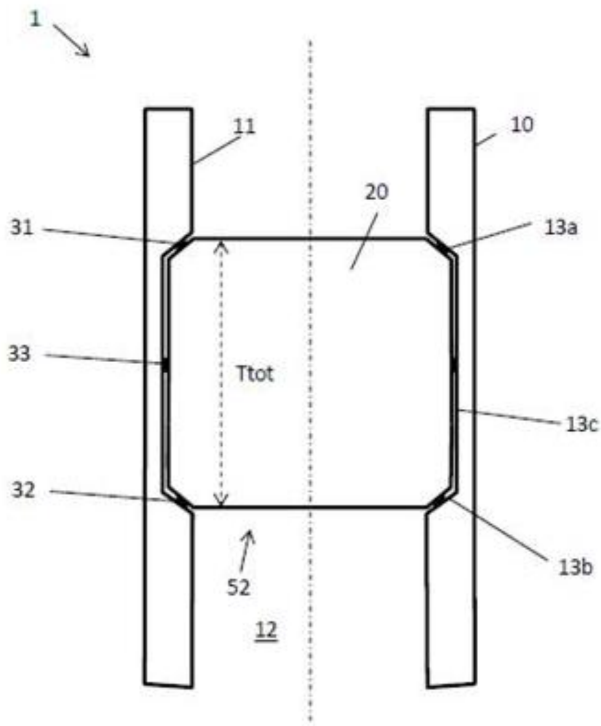
(73)	Applicant	Vosstech AS, Bjørgavegen 34, 5709 VOSS, Norge
(72)	Inventor	Stig Ove Bjørgum, Bjørgavegen 23, 5709 VOSS, Norge Espen Hiorth, Konrad Dahls veg 3, 7024 TRONDHEIM, Norge
(74)	Agent of attorney	Onsagers AS, Postboks 1813 Vika, 0123 OSLO, Norge

(54) Title **Plugging device with glass disc made of industrial glass**

(57) Abstract

The present invention relates to a well tool device (1) with a frangible disc (20). The device (1) comprises a housing (10) having an inner surface (11) defining a through bore (12) and a seat (13) for supporting the frangible disc (20) in relation to the housing (10). In addition, sealing devices (31, 32, 33) are provided between the frangible disc (20) and the seat (13). The frangible disc (20) comprises one hardened glass disc body (52) made of industrial glass.



FIELD OF THE INVENTION

The present invention relates to a well tool device.

BACKGROUND OF THE INVENTION

Well tool devices, such as 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.

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 frangible barrier element into small pieces.

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. According to http://www.tco.no/high-durability-glass/category57.html, the high durability glass material is soda lime float glass which is "hardened and tempered" to meet the "requirements regarding maximum strength and minimum particle size after being shattered".

Another glass plug is known from NO 20130427 (Vosstech AS). Here, the plug has one glass disc made of float glass, which may be disintegrated by a radial pin or loading device being pushed into the glass disc. However, there is a limitation in how high pressure this glass disc may withstand.

As mentioned above, glass disks made of float glass of soda lime type are commonly used in such well plugs. Float glass of soda lime type is produced at a standard thicknesses, for this type of well tools the thicknesses 16, 19 and 25 mm are used. The maximum thickness of float glass is 25 mm. The maximum pressure one glass disc may withstand will depend on its thickness, the glass quality and the diameter of the glass disc. Hence, this maximum thickness of 25 mm represents a pressure limit for the glass plug if only one disc is used. If the glass plug is to be used for higher pressures and higher diameters, several such glass discs must be used together in order to withstand higher pressures. The above NO 321 976 shows an example where several glass discs are assembled with an intermediate layer into one larger glass disc body.

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

With the above prior art well plugs, different types of seals are used between the seat in the metal housing and the glass. This metal housing including the seat is made of a high quality stainless steel material. Contact between this metal housing and the glass disc are not allowed, as this will cause the glass to shatter when pressure is applied to the glass disk.

Therefore, one type of seal (typically o-ring) is used circumferentially around the glass disc as a pressure seal to avoid contact and also to avoid fluid flow between the glass disc and the metal housing and a second type of seal, a contact preventing seal, is used as a seal in the upper part and lower part of the seat to avoid contact between the glass disc and the seat, for transferring the fluid pressure as a force from the glass disk to the metal housing without unintentional disintegration of the glass disc. The second type of seal is often made of a thermoplastic polymer material which may withstand high pressures. However, the non-metallic material may not be as useful when higher temperatures are expected in an oil and/or gas well. For example, if the well temperature is expected to be above 130 °C at pressures of ca 4000 PSI, then these thermoplastic polymer materials will not be able to prevent contact between the glass disc and the metallic material of the seat in the housing anymore.

Hence, another object of the invention is to provide a well plug having one glass disc body which can be used at higher temperatures.

It has also been found that the quality of float glass of soda lime type is a problem. First of all, it has been found that the maximum pressure each such glass disc may withstand is variating a lot – even for glass discs produced from the same batch of float glass (i.e. glass discs cut from the same float glass plate may have different quality). Secondly, it has been found that if a polishing process is performed on the glass discs in order to remove smaller scratches in the surface of the glass disc before the hardening process, the scratches themselves or the polishing process reduces the maximum pressure for these glass discs. Accordingly, the reliability of these glass discs has been low. During the development and testing of prototypes for higher pressures, ca 30% of the glass discs has turned out to be wreckage.

Accordingly, the object of the invention is to reduce the wreckage of glass discs and to achieve glass discs which can withstand higher pressures even though a polishing process has been performed on them to remove smaller scratches in their surface.

When the well tool device is set in a well, it is in some situations desired to know whether the fluid below the frangible glass disc is a gas or a liquid. If gas is present, precautions, such as to add weight to the liquid column above the glass disc, may be necessary before the glass disc is shattered to avoid the risk of a blowout.

SUMMARY OF THE INVENTION

The present invention relates to a well tool device comprising:

- a housing having an inner surface defining a through bore;

- a frangible disc;

- a seat for supporting the frangible disc in relation to the housing;

- sealing devices (31, 32, 33) provided between the frangible disc and the seat;

where the frangible disc comprises one hardened glass disc body made of industrial glass.

In one aspect, the one hardened glass disc body is convex.

In one aspect, the one hardened glass disc body has been exposed to a grinding process before the hardening process.

In one aspect, the one hardened glass disc body has been exposed to a polishing process before the hardening process.

In one aspect, the one hardened glass disc body has been cut from an industrial glass block. The glass block may be rectangular box-shaped block, or cylindrical.

In one aspect, the thickness (Ttot) of the one hardened glass disc body is above 25 mm, preferably 30 - 40 mm. In other embodiments, the thickness may be even higher.

In one aspect, the well tool device further comprises a sensor device provided on a first side of the hardened glass disc body.

In one aspect, the sensor device is a light sensor device for monitoring the status on a second side, opposite of the first side, of the one hardened glass disc body.

In one aspect, a buoyancy device is connected to the sensor device.

In one aspect, the one hardened glass disc body made of industrial glass is made of borosilicate glass.

In one aspect, the one hardened glass disc body has been molded to a predetermined shape, where the predetermined shape defines the shape of upper and lower surfaces of the body and where the shaping of upper and lower chamfered surfaces and a side surface of the body is performed by a grinding and/or polishing process.

DETAILED DESCRIPTION

Embodiments of the invention will now be described with reference to the enclosed drawings, where:
Fig. 1a illustrates a cross section of a prior art well tool device;
Fig. 1b illustrates a cross section of a prior art frangible glass disc;
Fig. 2 illustrates a perspective view of a industrial glass block;
Fig. 3 illustrates a perspective view of a glass disc body cut from the industrial glass block and grinded/polished to a cylindrical shape;
Fig. 4 illustrates a perspective view of the glass disc body grinded/polished with chamfered surfaces;
Fig. 5 illustrates a cross sectional view of the glass disc body in fig. 4;
Fig. 6 illustrates a second embodiment of the glass disc body in fig. 3, with an increased thickness;
Fig. 7 illustrates a cross section of a well tool device with the glass disc body of fig. 6;
Fig. 8 illustrates the well tool device with a sensor device;
Fig. 9 illustrates a side view of an alternative embodiment of the glass disc body;
Fig. 10 illustrates a side view of yet an alternative embodiment of the glass disc body;
Fig. 11 illustrates a perspective view of the embodiment in fig. 9.

Initially, a prior art well tool device 1 will be described with reference to fig. 1a and 1b. The well tool device 1 comprises a housing 10 having an inner surface 11 defining a through bore 12. A seat 13 is provided in the inner surface 11 of the housing 10. The seat 13 has an upper chamfered seat surface 13a, a lower chamfered surface 13b and a side surface 13c provided between the upper and lower chamfered surfaces 13a, 13b. The side surface 13c is typically provided in an axial direction, i.e. parallel to the longitudinal axis I of the well tool device 1.

A frangible disc 20 is provided in the seat 13 of the housing 10. The frangible disc 20 also comprises upper and lower chamfered surfaces 20a, 20b and a side surface 20c. The size and shape of the seat 13 and the frangible disc 20 are adapted to each other, in order to seal off the through bore 12. As float glass is used, the frangible disc 20 comprises an upper planar surface 20e and a lower planar surface 20f.

The housing 10 and the frangible disc 20 are typically cylindrical, as the well they are lowered into are substantially cylindrical.

An upper sealing device 31 is provided between the upper chamfered surface 20a of the frangible disc 20 and the upper seat surface 13a and a lower sealing device 32 is provided between the lower chamfered surface 20b of the frangible disc 20 and the lower seat surface 13b. The purpose of the upper and lower sealing devices 31 is, as mentioned in the introduction above, to prevent contact between the frangible chamfered disc and the seat 13 when a high pressure is applied to the frangible chamfered disc, as such contact is known to disintegrate the frangible disc.

A sealing device 33 is provided between circumferentially around the frangible disc, i.e. between the side surface 20c and the side surface 13c. The purpose of the sealing device 33 is, as mentioned in the introduction above, to prevent fluid from flowing between the upper and lower side of the frangible disc 20.

It is known that the frangible disc 20 can be made of float glass of soda lime type. Today, the highest available thickness Ttot for such float glass of acceptable quality is presently 25 mm as mentioned in the introduction above.

The present invention will now be described with reference to fig. 2 - 8. It should be noted that the well tool device 1 according to the invention also comprises the housing 10 with the seat 13, a frangible disc 20 and sealing devices 31, 32, 33 provided between the frangible disc 20 and the housing 10.

The well tool device 1 according to the invention uses a frangible disc 20 comprising one hardened glass disc body 52 made of industrial glass.

Industrial glass may be bought as a block 50, as shown in fig. 2. The block 50 is typically a rectangular block. Several types of industrial glass are possible to use, for example crown glass, which is a type of optical glass typically used in lenses and other optical components. One type of such crown glass is borosilicate glass, often shortened as BK7, which is typically comprising 70% SiO_2, 8.4% Na_2O, 8.4% K_2O, 10% B_2O_3 and 2,5% BaO by weight. In comparison, float glass of soda lime type typically comprises 72% SiO_2, 13.5% Na_2O, 8.5% CaO, 3.5% MgO and 1.5% Al_2O_3 by weight. It should be noted that these compositions may vary slightly between producers.

From the industrial glass block 50 glass disc bodies 52 can be cut into a desired thickness Ttot as shown in fig. 2. The cutting may be performed by a saw, a cutting wire, a water jet etc.

Then a grinding process is performed on the glass disc body 52 in order to achieve a cylindrical shape, as shown in fig. 3. Then, a grinding process is performed in order to achieve the chamfered surfaces 20a, 20b, as shown in fig. 4 and 5.

The glass disc body 52 is then hardened in a hardening process before it can be used as a frangible disc in the well tool device 1.

During the development of the present invention, it have been found that glass disc bodies 52 made of industrial glass have more uniform quality, i.e. the quality is not variating as much as the discs of float glass. Moreover, it has been found that the industrial glass disc bodies 52 may be polished, for example after the cutting and grinding process, but before the hardening process. Hence, it is possible to remove smaller scratches from the surface of the bodies without reducing their quality.

Accordingly, a more predictable production process is possible, since it is the thickness Ttot of the body 52 that is determining the maximum pressure the disc can withstand. Moreover, it is achieved that the wreckage of glass discs is considerably reduced.

It is now referred to fig. 6 and 7. Here it is shown that the thickness Ttot of the one hardened glass disc body is well above 25 mm (as shown in the prior art of fig. 1a), preferably the thickness Ttot is in the range of 30 – 40 mm or even above 40 or 50 mm. Of course, the thickness will be dependent on several factors, such as the expected differential pressure and the diameter of the glass disc. For higher diameters of the well tool device, a thicker glass disc will be needed for the same differential pressure.

With prior art float glass discs, this is not possible, as the maximum thickness for one such float glass disc is 25 mm.

During tests it has been found that the one hardened glass disc body 52 will disintegrate into smaller glass fragments if a pin or spear is forced towards the hardened glass disc body 52. Hence, the behavior of the one hardened glass disc body 52 made of industrial glass is similar to the prior art glass disc of float glass type when it comes to disintegration of the disc.

It is now referred to fig. 8. Here it is shown that the well tool device 1 further comprises a sensor device 60 provided on a first side of the hardened glass disc body. The sensor device 60 is preferably provided adjacent to, or in contact with the upper side of the one hardened glass disc body 52.

The sensor device 60 may for example be a sensor device for sensing light, in order to monitor the status on the lower side, opposite of the first side, of the one hardened glass disc body. It should be noted that the upper side here is the side facing towards the topside of the well, while the lower side is the side facing towards the bottom of the well. The sensor device may for example be a digital camera device.

The sensor device may be set in the well together with the well tool device 1, or it may be lowered into the well after the well tool device 1 has been set.

The sensor device may comprise a storing unit for storing of the sensed data, and then these sensed data can be analyzed after a retrieval of the sensor device from the well. Alternatively, the sensor device 60 may comprise a communication unit 61 for transferring sensed data wirelessly or via a wire to the topside. Hence, it is possible to visually detect if there is a liquid or if there is gas below the glass disc body 52 and take precautions if gas is present.

The abovementioned industrial glass is transparent; even with thicknesses well above 25 mm. Float glass of soda lime type have a greenish color, which reduces the transparency through the disc. In addition, for high pressure applications, float glass of soda lime type must be stacked above each other with a lamination layer between (as known from NO 321 976), which will reduce the transparency considerably.

The sensor device 60 may further comprise a buoyancy device 62, to ensure that the sensor device 60 (and possibly also the communication unit 61) is floating upwards with the well flow after disintegration of the frangible disc.

The well tool device 1 may further comprise a downhole sensor 70 located on the lower side of the frangible glass disc body 52. The downhole sensor 70 may be connected to the housing 10 or to the glass disc body 52. The downhole sensor 70 preferably comprises a display 71 for showing the status of the sensor device 70. The display 71 is faced upwardly towards the sensor device 60.

The downhole sensor 70 may for example be a gas sensor, where the display 71 is showing a red color when gas is detected and a green color when gas is not detected, alternatively the display 71 comprises a diode which is emitting light when gas is detected and where the diode is turned off when gas is not detected. The color or light of the display 71 may then be observed by the sensor device 60 through the glass disc body 52.

The sensor device 60 may also be used to monitor the status of other components, for example a gas lift valve, located below the glass disc body 52.

It is now referred to fig. 9 and 10. Here it is shown that the one hardened glass disc body 52 is convex, i.e. that the upper and lower surfaces 20e, 20f are curved as a lens. In fig. 9, the one hardened glass disc body 52 has a radius r1 indicating the curvature of the upper convex surface 20e and in fig. 10 the one hardened glass disc body 52 has a radius r2 indicating the curvature of the upper convex surface 20e. In fig. 9, r1 is equal to 2.7 x R1, where R1 is the radius of the disc, and in fig. 10, r2 is equal to 1.3 x R2, where R2 is the radius of the disc. It should be noted that a flat disc will have a radius r for the curvature equal to ∞ while a curvature of a sphere will have a radius r equal to the radius R of the disc.

It fig. 9 and 10, the bodies 52 are biconvex, i.e. the upper and lower convex surfaces are curved. It would also be possible with a plano-convex glass disc body 52, i.e. where one of the surfaces 20e, 20f is convex and the opposite one is planar.

These convex glass disc bodies 52 are difficult or even impossible to achieve with prior art float glass discs, as a grinding and/or polishing process is needed, and where this grinding/polishing process has shown to damage the possibility for the float glass discs to withstand higher pressures. Moreover, the curvature, i.e. the above radiuses r1, r2 will be very low due to the limited thickness of float glass.

Alternatively, the industrial glass block 50 may be bought as a cylindrical block in a suitable diameter, in order to reduce the amount of grinding and/or polishing.

In yet an alternative embodiment, the industrial glass block is molded to a predetermined shape, for example a shape having convex upper and lower surfaces 20e, 20f. In such an alternative embodiment, the upper and lower chamfered surfaces 20a, 20b and the side surface 20c are shaped by a grinding and/or polishing process

A preliminary test has shown that a well tool device with one hardened glass disc body 52 made of industrial glass with thickness Ttot = 30 mm could withstand a pressure of 12500 psi. The test was stopped as pipes/valves of the testing equipment was not rated for higher pressures.

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);

- a seat (13) for supporting the frangible disc (20) in relation to the housing (10);

- sealing devices (31, 32, 33) provided between the frangible disc (20) and the seat (13);

characterized in that:

- the frangible disc (20) comprises one hardened glass disc body (52) made of industrial glass.

2. Well tool device (1) according to claim 1, where the one hardened glass disc body (52) is convex.

3. Well tool device (1) according to claim 1 or 2, where the one hardened glass disc body (52) has been exposed to a grinding process before the hardening process.

4. Well tool device (1) according to any one of claims 1 - 3, where the one hardened glass disc body (52) has been exposed to a polishing process before the hardening process.

5. Well tool device (1) according to any one of claims 1 - 4, where the one hardened glass disc body (52) has been cut from an industrial glass block (50).

6. Well tool device (1) according to any one of the above claims, where the thickness (Ttot) of the one hardened glass disc body is above 25 mm, preferably 30 - 40 mm.

7. Well tool device (1) according to any one of the above claims, where the well tool device (1) further comprises a sensor device (60) provided on a first side of the hardened glass disc body.

8. Well tool device (1) according to claim 7, where the sensor device (60) is a light sensor device for monitoring the status on a second side, opposite of the first side, of the one hardened glass disc body.

9. Well tool device (1) according to claim 7, where a buoyancy device (62) is connected to the sensor device (61).

10. Well tool device (1) according to any one of the above claims, where the one hardened glass disc body (52) made of industrial glass is made of borosilicate glass.

11. Well tool device (1) according to any one of claims 1 - 4, where the one hardened glass disc body (52) has been molded to a predetermined shape, where the predetermined shape defines the shape of upper and lower surfaces (20e, 20f) of the body (52) and where the shaping of upper and lower chamfered surfaces (20a, 20b) and a side surface (20c) of the body (52) is performed by a grinding and/or polishing process.

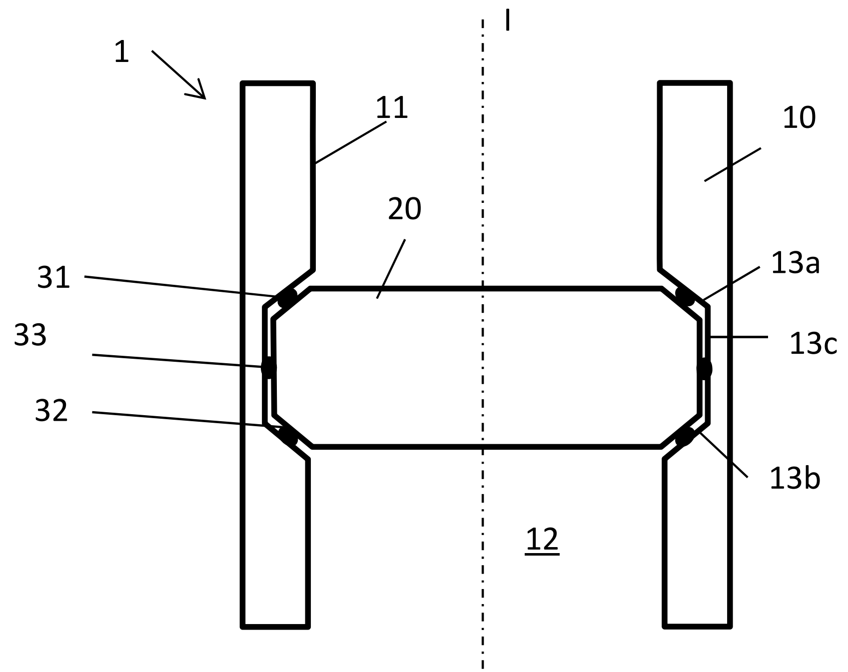


Fig. 1a: Prior art

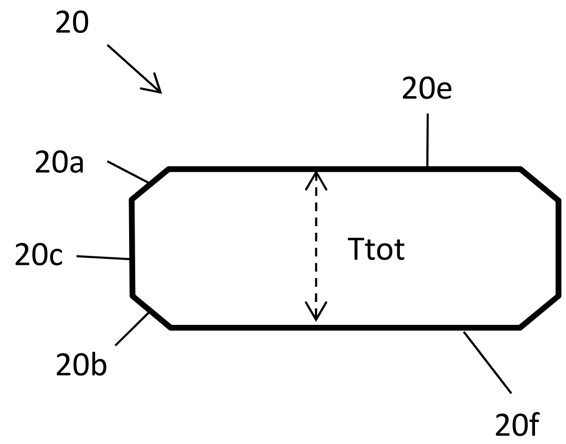


Fig. 1b: Prior art

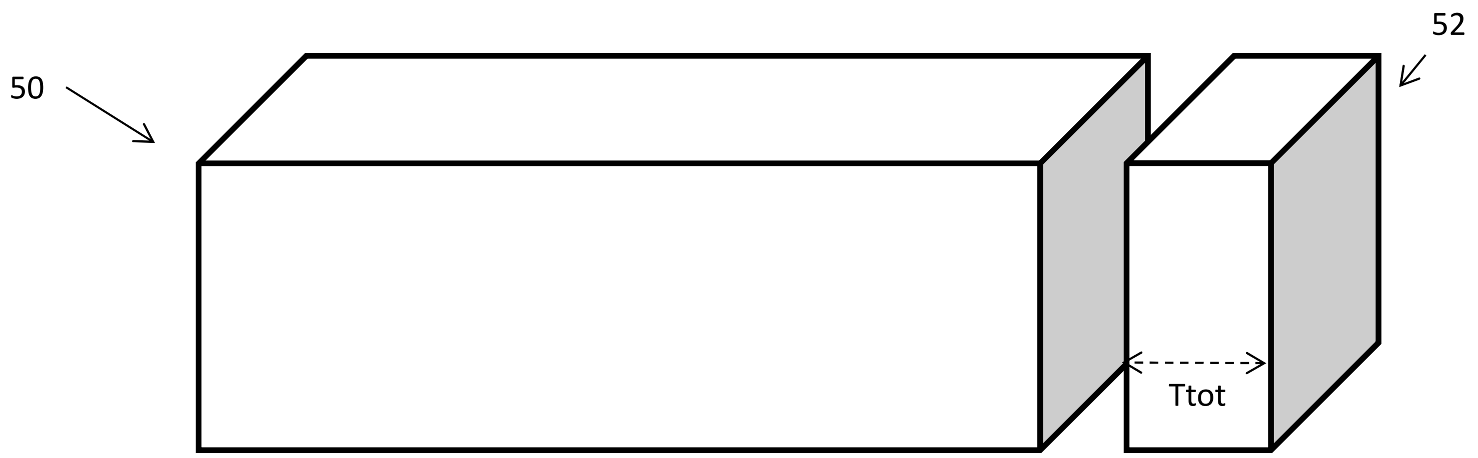


Fig. 2

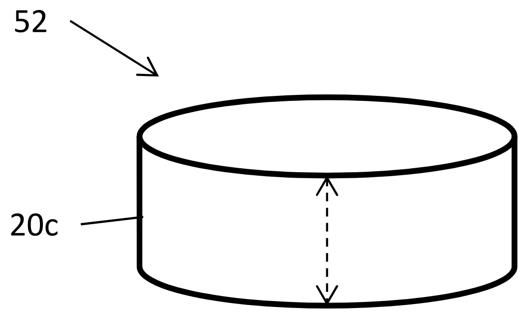


Fig. 3

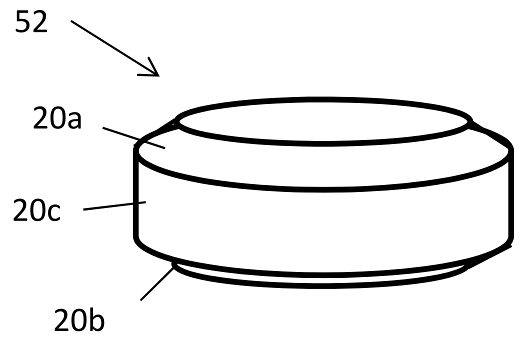


Fig. 4

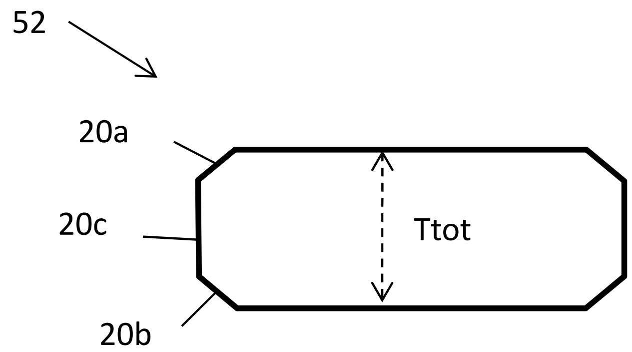


Fig. 5

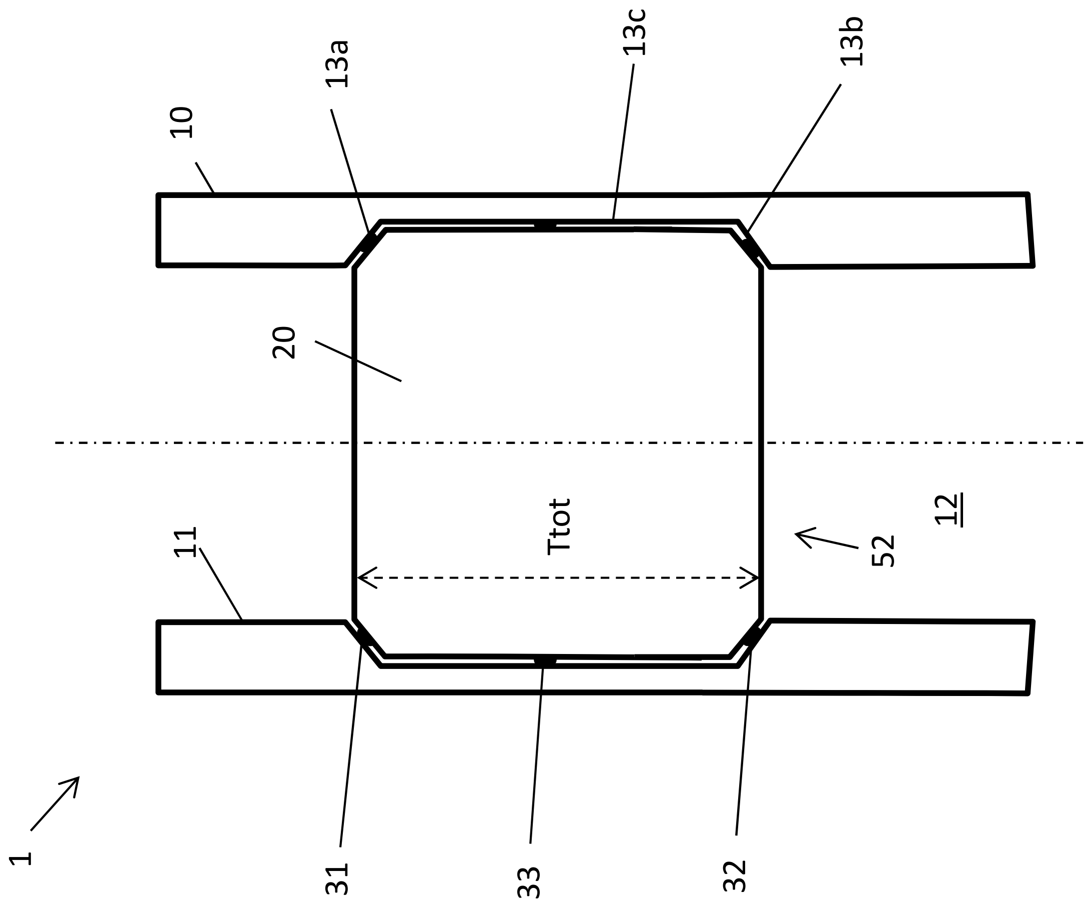


Fig. 7

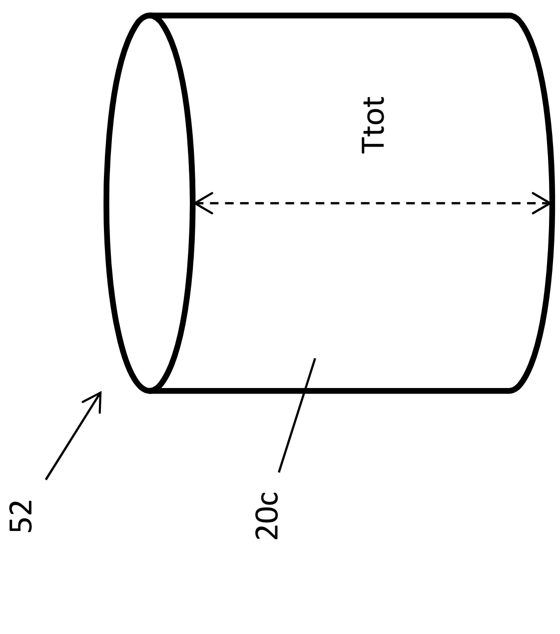


Fig. 6

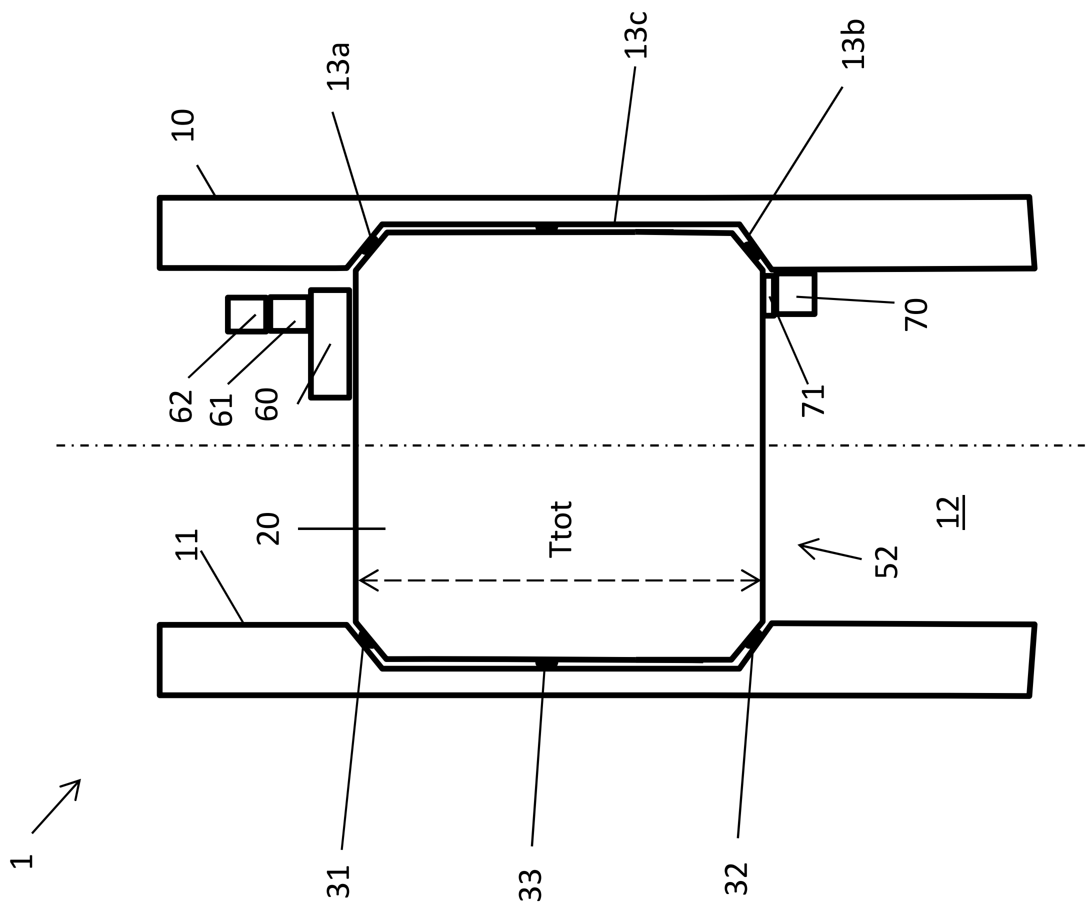


Fig. 8

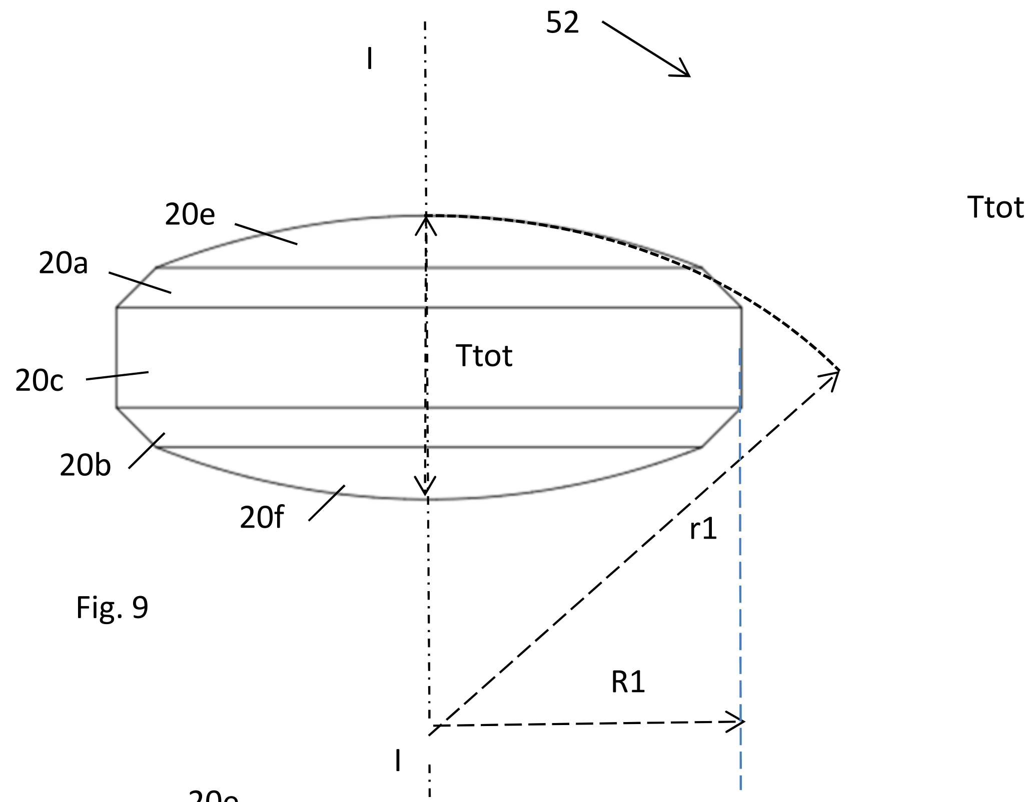


Fig. 9

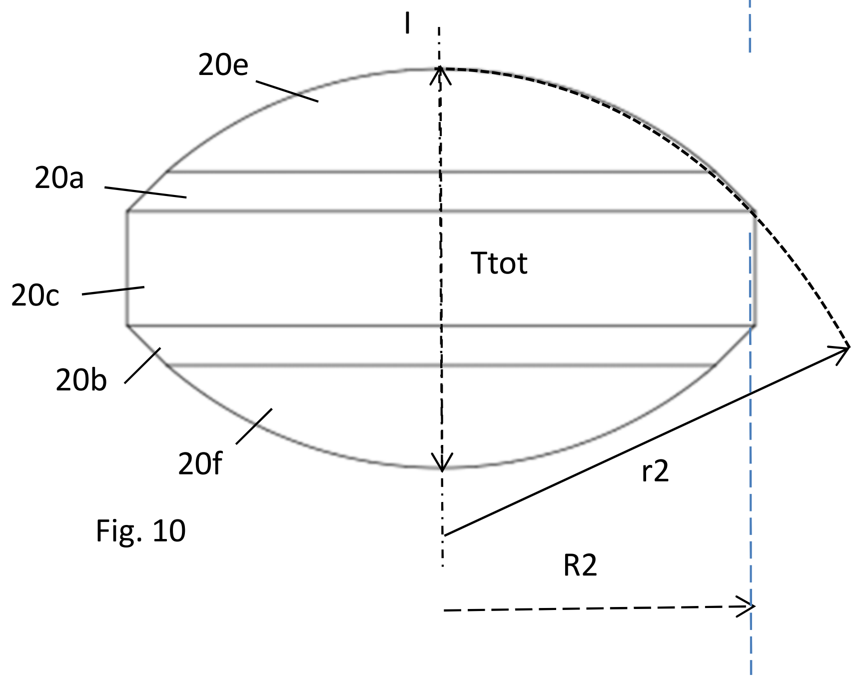


Fig. 10

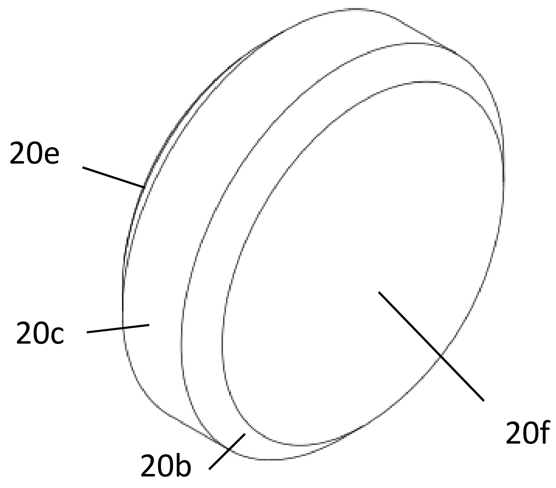


Fig. 11