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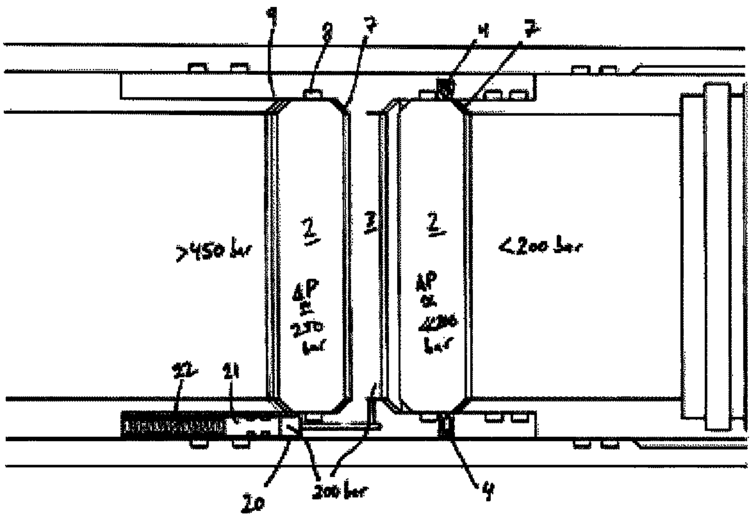
(73)	Applicant	TCO AS, Storaneset 20, 5260 INDRE ARNA, Norge
(72)	Inventor	Viggo Brandsdal, Burastien 48, 5265 YTRE ARNA, Norge Jan Tore Tveranger, Garnestona 2, 5264 GARNES, Norge
(74)	Agent of attorney	Zacco Norway AS, Postboks 2003 Vika, 0125 OSLO, Norge

(54) Title **Crushable plug**

(57) Abstract

The present invention relates to a plug (1) comprising at least two discrete glass discs (2), wherein there is provided between the glass discs a liquid (3) which contributes to load uptake and load distribution, and a pin-/claw device (4) is arranged to be pressed in a radial direction into at least one of the glass discs (2). A distinctive feature of the plug is that it does not include a functional drainage system, and the pin-/claw device (4) is arranged such that on activation there occurs a pressure leakage through the glass disc (2). Also suggested according to the invention is a volume compensator/constant pressure regulator (20, 21, 22; 23; 24).



Crushable plug

The present invention relates to a decomposable sealing device designed for pressure testing, zone isolation and workover of a borehole.

It is known to use plugs of a decomposable material, such as glass, ceramics, salt, etc., where the plug can be removed or crushed after use in such a way as to leave behind few remains or fragments. If correctly constructed, such plugs of decomposable material can be removed with or without explosives in a predictable and secure manner.

Plugs comprising two or more layers of glass stacked atop one another can be removed without using explosives by employing techniques that include percussive tools, pigs inserted into the decomposable material, spheres or other articles that serve to create tensions in the decomposable material, or by puncturing the layer disposed between the two or more glass strata, where the volume contains a film or a sheet of a material other than glass.

This layer between the two or more glass strata, comprising a film and/or a sheet of material other than glass, may comprise a fluid, a plastic material, a rubber material, a felt material, a paper material, glue, grease, etc. The volume, which may be filled with at least one of the aforementioned materials, will enable the plug to attain the desired strength and toughness during use by providing for uptake of loads exerted on the plug in the form of a differential pressure between the underside and top side of the plug.

It is a fact that the surface of a glass area, regardless of how or how much it has been treated, polished and honed, will never be completely smooth and flat. The surface will always have a topology that will form point loads if measures are not provided to counteract these. Moreover, glass under stress will bend and move in such a way that it is virtually unthinkable to stack two glass discs atop one another without having something between them to form an intermediate space or volume between the glasses which is filled with a different material from glass.

If two glass surfaces are laid directly atop one another without anything in between, there will always arise point loads, and thereby tensions, in the interface due to the aforementioned topology. These point loads/tensions will have the result that the plug fails to attain the desired strength and toughness, and the strength, toughness and other desirable properties for the plug become extremely uncertain and unpredictable. It will be uncertain and unpredictable not only as to whether the plug is strong and tough enough, but also as to whether the plug will disintegrate and be removable with the pressure reserves or other means at one's disposal to destroy a plug when it is time for this. If a plug cannot be removed at the desired time and/or by intended means, then quite expensive and time-consuming measures must be initiated, which is not a desirable situation.

NO321976, filed on 21 November 2003, describes a glass plug comprising a plurality of layered or stratified glass discs having between them layers of a material other than glass. NO 321976 is the first patent publication ever to describe a layered glass plug. NO 321976 explains why layers of a material other than glass must be provided between the glass discs and is incorporated herein in its entirety as a particularly relevant reference.

NO325431, filed on 23 March 2006, relates to an apparatus and method for crushing a decomposable sealing device of the aforementioned type. NO325431 employs a relief chamber and an adjustable connecting means forming a fluid communication channel between the volume between the glass discs and relief chamber when the adjustable connecting means is set in open position. When the adjustable connecting means is set in open position, the content between the glass discs is "punctured" and evacuated, and the load on (one or more of) the glass strata exceeds the level they are designed to tolerate, causing them to be crushed. In addition, the apparatus according to NO325431 comprises a number of pin devices arranged to point load the glass strata when the connecting means is reset, where these pin devices further serve to crush the glass strata in a safe manner when the connecting means is reset. Hence, NO325431 shall function such that the plug is crushed by resetting the connecting means to an open position, so that the space between the glass strata is punctured and the pressure falls drastically and quickly. The pressure support function will thereby disappear, the glass strata will bend until they rupture and they will disintegrate one by one. In addition, NO 325431 discloses the possibility of mounting pins around the glass strata, the pins being arranged to produce point loads in the glass to weaken the strength of the glass strata. As their function is described in NO325431, the pins then either function «passively» -- i.e. they stand still and come into contact with the glass strata when those are bent or after the adjustable connecting means is activated, or the pins are «actively» actuated by means of the adjustable connecting means when activated -- i.e., the pins are pushed against the glass strata and thereby produce the point load. In both cases, the point loads from the pins are directly caused by activation of the adjustable connecting means. The disclosed function of the plug is conditional on the space between the glass strata being punctured and the pressure falling drastically and quickly, with the glass strata thus being bent and thereby point loaded. Alternatively, the sum of the tensions arising in the glass strata when the space between the glass strata is punctured/evacuated *and* the pins are forced into the glass strata exceeds the level of tolerance, causing them to rupture. Hence, the pins do not function alone, but are dependent on the evacuation of the content between the glass strata.

NO331150 discloses a crushable plug, for example of glass, which comprises a plurality of pin devices (studs, claws, tips, points, compression ring) which are caused to be forced radially into a glass stratum so that it is crushed, said glass stratum comprising previously formed weakened points/areas that facilitate the crushing when the pin devices are pressed in against the plug. It is further disclosed in NO331150 that the weakened areas are formed when the glass contains microcracks, like those occurring through grinding. Looking at Fig. 3 in NO331150, one then sees indicated cracks spreading inwardly in the glass from the points of the pin devices. This type of crack formation is what is assumed to have occurred when glass plugs of these kinds are crushed. Since the glass strata are pulverized by crushing, it has thus not been evident how the glass layers are crushed. NO331150 shows a plug comprising one single glass stratum. Although the description does not rule this out, NO331150 shows no embodiments comprising several glass strata. Therefore, NO331150 gives no instruction as to how the disclosed solution could potentially be adapted to a plug comprising more than one glass stratum.

The present invention relates to a crushable plug comprising two or more glass strata, wherein the plug is removed without the use of explosives and without the need for any drainage or evacuation system.

In addition, the invention relates to an arrangement that distributes the load between the glass discs and contributes toward compensating for a change in volume when one of the glass discs moves.

In one exemplary embodiment, such an arrangement may comprise a piston and spring device, where the piston exerts a pressure against the liquid between the glass discs, and wherein the spring and its properties determine how great this pressure is to be. Other arrangements, for example, a metal bellows or other volume compensator- and/or constant pressure regulators for load distribution, may also be employed.

In an especially simple embodiment of the invention, the liquid between the glass discs is pressurized beforehand, e.g. to 100 bar, this pressure being chosen to "match" the maximum pressure that the plug must tolerate during testing, so that the load distribution between the glass discs is as optimal as possible when the load on the plug is greatest.

In the following is provided a detailed description of embodiments of the present invention, with reference to the attached drawings, wherein:

Fig. 1 shows an embodiment of the present invention prior to crushing,

Fig. 2 shows the embodiment in Fig. 1 after one of the glasses has crackled and is about to rupture,

Fig. 3 shows the embodiment in Fig. 1 after both of the glasses have crackled and are about to rupture,

Fig. 4 shows an embodiment of a volume compensator/constant pressure regulator according to the present invention, wherein the intermediate space between the glasses is pressurized before the plug is subjected to the differential pressure for which it is constructed,

Fig. 5 shows the same embodiment as in Fig. 4, wherein the pressure has now accumulated across the plug with greatest pressure being over the plug,

Fig. 6 shows the same embodiment as in Fig. 4, wherein the pressure has now accumulated across the plug with the greatest pressure being below the plug,

Fig. 7 shows a second embodiment of a volume compensator/constant pressure regulator according to the present invention, comprising a bellows instead of a piston and a spring,

Fig. 8 shows a third embodiment of a volume compensator/constant pressure regulator according to the present invention, comprising a balloon, bubble, sphere, or the like, wherein the intermediate space between the glasses is pressurized before the plug is subjected to the differential pressure for which it is constructed, and

Fig. 9 shows the same embodiment as in Fig. 8, wherein the balloon, bubble, sphere or the like is compressed because the glasses are pressed together and the volume between the glasses has become smaller.

Fig. 1 shows an embodiment of a plug 1 according to the present invention. This embodiment comprises two discrete glass discs 2. Between the glass discs is provided a liquid 3 which contributes toward load uptake and load distribution. Around or alongside at least one of the glass discs is provided a pin-/claw device 4 which is arranged to be forced in a radial direction into the glass disc 2 around or beside which it is mounted. It is understood that the pin-/claw device 4 may comprise one or more pin- or claw means, and if there are several, that these may be mounted evenly or unevenly around the glass disc. This pin-/claw device is arranged to cause a pressure leakage through the glass discs when activated. The pin-/claw device 4 is activated in a manner suited thereto; see for example NO 331150 or NO325431.

The pin-/claw device 4 may also be shot, struck or activated in an axial direction from above or below; it need not be activated radially. This is not shown in the drawings, but is inherent in the idea and core of the invention.

According to one embodiment of the present invention, at least one of the glass discs is provided with one or more weakening zones 5, said weakening zone or zones being formed such that, in addition to facilitating the crushing, the glass disc is also crushed in such a manner as to cause a predictable pressure leakage 6 through the glass disc (ref. Fig. 2).

The aforementioned pressure leakage, whether facilitated by the weakening zones or not, is conditional on there being at least one fracture surface through the glass disc extending from the top side to the underside of the glass disc (see Fig. 2).

Further, it has been surprisingly discovered through experiments and test analyses that plugs comprising drainage systems and pin devices do not, in reality, require drainage systems at all. The previously assumed causal relationship between activation of the drainage system and the function of the pin devices is at best weak and probably non-existent. This means that the drainage system is superfluous and unnecessary, with the result that one is able both to save considerable costs and to avoid unnecessary complexity and vulnerability by simply eliminating the drainage system. The conventional gas plugs that currently comprise a liquid between the glass discs in addition to a drainage system and a pin-/claw device (ref. NO325431) in reality do not need the drainage system at all, at least not if the pin-/claw device is designed such that a pressure leakage occurs in accordance with the present invention. As a result, it is possible to produce a plug that comprises fewer parts, has fewer potential leakage spots, is more reliable, is less expensive to manufacture, is simpler to produce, and will be easier to certify.

It is thus an essential feature of the present invention that the plug does not include or require a drainage system comprising a drainage hole, drainage chamber, etc. All these elements and parts included in such a drainage system increase the complexity, and thereby the vulnerability, of a plug of this type.

In a second embodiment of the invention, the distance between the glass discs is sufficient to allow each of the glass discs adequate space to collapse more or less completely into it after crackling of the glass disc. It has been shown, in fact, that a crackled glass disc can have considerable load carrying capacity if given support, partially or entirely, by an adjacent glass disc, an intermediate film of, e.g., a viscous liquid, glue, grease, or a layer of felt, paper or plastic.

Fig. 2 shows the same plug as in Fig. 1, but now with a crackled 6 glass disc 2 with pressure leakage through it. It is understood that the features indicated in the drawings and this text are merely examples for illustrative purposes. While the plug is still intact, as shown in Fig. 1, the total pressure difference of 300 bar is distributed across the two glass discs such that the pressure difference over each of the glass discs is about 150 bar. A liquid 3 between the glass discs functions as a pressure-uptake and pressure-distributing medium. The liquid 3 receives and thereby distributes the pressure load between the two glass discs 2. In Fig. 2 the pin-/claw device 4 is activated, e.g., in accordance with what is described in NO331150, so that at least one of the glass discs 2 is crackled and has at least one through-going crack 6 that has provided for a pressure leakage through this at least one glass disc 2. As a result of the pressure leakage, there is now an approximately zero pressure difference across the crackled 6 glass disc, and almost the entire original pressure difference of 300 bar across the intact plug is now accumulated over the remaining glass disc. None of the glass discs are constructed to tolerate a pressure difference of 300 bar; they are designed for a pressure difference of, for example, maximum 200 bar. Thus, the second glass disc ruptures and the plug disappears. Fig. 3 shows an example wherein both of the glasses are crackled, since a pressure leakage has occurred through both glass discs.

It is understood that it is also possible to have more than two glass discs.

Fig. 4 shows a volume compensator/constant pressure regulator 20 according to the invention. This comprises a piston 21 and a spring 22, where the spring has a prestress function with a selected spring constant enabling it to generate a pressure of, for example, 200 bar on liquid 3. This regulator 20 serves to distribute the load between the glass discs 2 and to compensate for volume changes when a glass disc moves. Even with small tolerances, the glass discs 2 will be in movement when the pressure difference across the plug increases during use. This may be a matter of small movements when the glass discs 2 settle into the gaskets 7, bending of the glass discs under a heavy load, or movements during surges or pressure changes, etc. The movement of the glass discs will necessarily cause volume changes in the liquid 3 between the glass discs, which will have a direct effect on the load distribution (ref. Fig. 5 and Fig. 6). One cannot risk ending up in a situation where one or the other (or a third, etc.) glass disc 2 is suddenly left with the major portion of the total pressure difference across the plug, a pressure difference that the remaining glass discs are not constructed to tolerate. The result would be an unwanted flushing of the plug.

Fig. 7 shows an alternative embodiment of such a volume compensator/constant pressure regulator. This comprises a bellows 23 made of metal or another compressible/flexible/ductile material having behind it a preloaded pressure reservoir that exerts a pressure against liquid 3 between the glasses. In principle, such a bellows is not unlike the combination of a piston and a spring, since the pressure reservoir functions as a spring and the surface of the bellows as a piston. Other alternative embodiments having a corresponding volume compensating effect may also be contemplated, for example as shown in Fig. 8, comprising a balloon, bubble, sphere or the like 24 made of a similar material as the bellows mentioned above. Fig. 9 shows the balloon, bubble, sphere or the like 24 in a more compressed state.

Although the volume compensator/constant pressure regulator according to the present invention is shown and explained in connection with a plug without a drainage system, the volume compensator/constant pressure regulator itself will function just as well in a plug having a drainage system. The objective of such a volume compensator/constant pressure regulator is to compensate for fluctuations when the glasses 2 move enough in relation to each other that the liquid volume changes. Therefore, if the volume between the glasses changes, it is advantageous to have some form of volume compensator/constant pressure regulator.

In other embodiments of glass plugs, where two or more glass members lie closer together with a more viscous liquid or other material having viscous properties, the need for a volume compensator/constant pressure regulator will not be as great. Figs. 1 to 3 show in principle a plug without a volume compensator/constant pressure regulator.

The volume compensator/constant pressure regulator according to the present invention, for use in connection with plugs of the aforementioned type, is thus distinguished by the feature that it exerts a predetermined pressure on liquid 3 located between glass discs 2.

If one chooses not to utilize some form of volume compensator/constant pressure regulator, then, according to the invention, one can provide for pressurization of liquid 3 between the glasses 2 while the plug is being assembled, e.g., at a pressure of 150 bar. This assumes that the clearance between glass discs 2, the gaskets and the seats 9 is quite small, so that the glass discs have minimal float between the seats. It could also be advantageous for the pressurized liquid 3 to be of a partially compressible type, permitting accommodation of a slight volume change without the pressure in the liquid disappearing entirely. In this respect, one can say that the partially compressible liquid in itself functions as a volume compensator. It is also conceivable to increase the liquid volume between glass discs 2 in combination with the use of a partially compressible liquid 3, thereby making it possible to "trim" the system's spring constant. The same can also apply to the design of the glass discs, which may be constructed to be more or less "stiff", such that volume changes during loading as a result of the bending of the glass discs will not be too great relative to the system's remaining capability to accommodate volume changes without losing too much liquid pressure. It is understood, as shown and explained above, that the pressure in liquid 3 is part of a pressure distribution calculation meant to ensure that the pressure difference across plug 1 is distributed between the glass discs in such a way that their tolerance threshold is not exceeded. Here it is understood that the load on each glass 2 is transferred to the glasses' respective seats 9, and that the pressurized liquid 3 has the capability of relieving a glass 2 with a pressure load corresponding to the pressure of liquid 3.

If the pressure difference across a plug 1 comprising two glass discs 2 is 350 bar, and the pressure of liquid 3 is 150 bar, then the glass that "sees" the greatest pressure is relieved by 150 bar, corresponding to the pressure in liquid 3, since the pressure that said glass must carry is 200 bar, while the second glass, the one that "sees" the lower pressure, must accommodate the remaining 150 bar that it "acquires" from the pressurized liquid, as this pressure of 150 bar is transferred to the seat against which this glass is resting. In any case, it is probably simpler and safer to arrange for a volume compensator/constant pressure regulator than to rely on the chance that the pressure in liquid 3 will be retained during and after assembly, transport, installation in a well, etc., but the latter is not impossible.

It is understood that the plug according to the present invention comprises the requisite number of gaskets and seals, designated in the figures by references numerals 7 and 8, respectively. In addition, the glass discs 2 are positioned in an appropriate manner on annular, slanted, shoulder-formed seats 9, which seats are arranged to receive the glasses 2 and to carry the compressive forces to which the glasses are subjected during use. Reference is made, in addition, to the cited reference documents that disclose a number of similar and different ways of designing such plugs.

Patent Claims

1. A plug (1) comprising at least two discrete glass discs (2), wherein there is provided between the glass discs a liquid (3) which contributes to load uptake and load distribution, and a pin-/claw device (4) is arranged to be pressed in a radial or axial direction into at least one of the glass discs (2), characterized in that the plug does *not* include a functional drainage system, and the pin-/claw device (4) is arranged such that on activation there occurs a pressure leakage through the glass disc (2).

2. A plug (1) according to claim 1, wherein the plug comprises a volume compensator/constant pressure regulator (20).

3. A plug (1) according to claim 2, wherein the volume compensator/constant pressure regulator (20) is in communication with a volume in which the liquid (3) is contained.

4. A plug (1) according to claim 3, wherein the volume compensator/constant pressure regulator (20) comprises a piston- (21) and spring arrangement (22).

5. A plug (1) according to claim 3, wherein the volume compensator/constant pressure regulator (20) comprises a pressurized metal bellows (23).

6. A plug (1) according to claim 3, wherein the volume compensator/constant pressure regulator (20) comprises a gas-filled balloon.

7. A plug (1) comprising at least two discrete glass discs (2), wherein there is provided between the glass discs a liquid (3) which contributes to load uptake and load distribution, and a pin-/claw device (4) is arranged to be pressed in a radial or axial direction into at least one of the glass discs (2), and a drainage system for evacuation of the liquid (3) on crushing, characterized in that the plug (1) includes a volume compensator/constant pressure regulator (20).

8. Plug (1) according to claim 6, wherein the volume compensator/constant pressure regulator (20) is in communication with a volume in which the liquid (3) is contained.

9. A plug (1) according to claim 7, wherein the volume compensator/constant pressure regulator (20) comprises a piston- (21) and spring arrangement (22).

10. A plug (1) according to claim 7, wherein the volume compensator/constant pressure regulator (20) comprises a pressurized metal bellows (23).

11. A plug (1) according to claim 7, wherein the volume compensator/constant pressure regulator (20) comprises a gas-filled balloon, bubble, sphere, or the like (24).

12. A plug (1) comprising at least two discrete glass discs (2), wherein there is provided between the glass discs a liquid (3) which contributes to load uptake and load distribution, and a pin-/claw device (4) arranged to be pressed in a radial or axial direction into at least one of the glass discs (2),
c h a r a c t e r i z e d i n that the plug does *not* include a functional drainage system and does *not* include a volume compensator/constant pressure regulator, wherein the liquid (3) is pressurized to a predetermined pressure, and the pin-/claw device (4) is arranged such that on activation there occurs a pressure leakage through the glass disc (2).

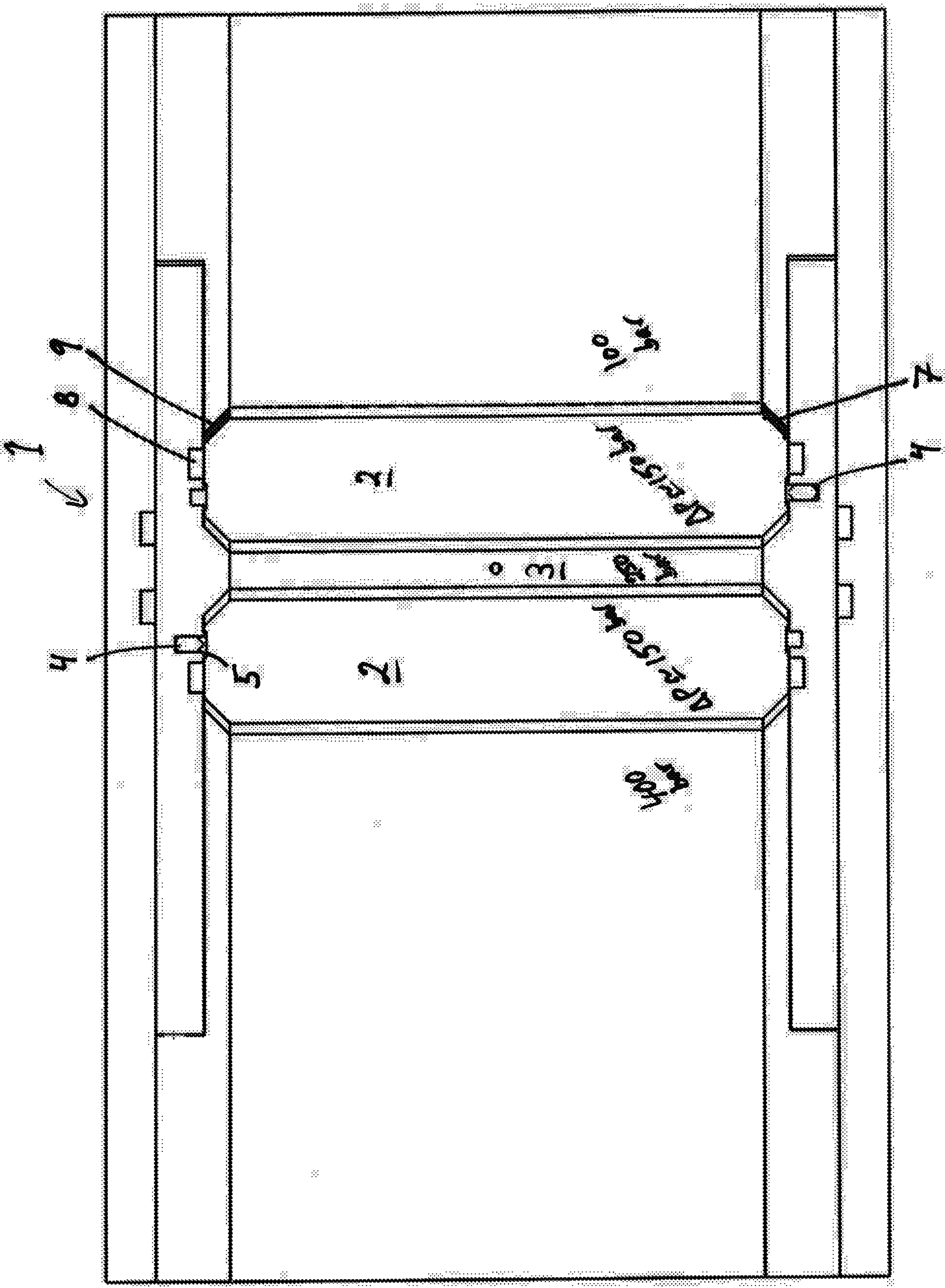


Fig. 1

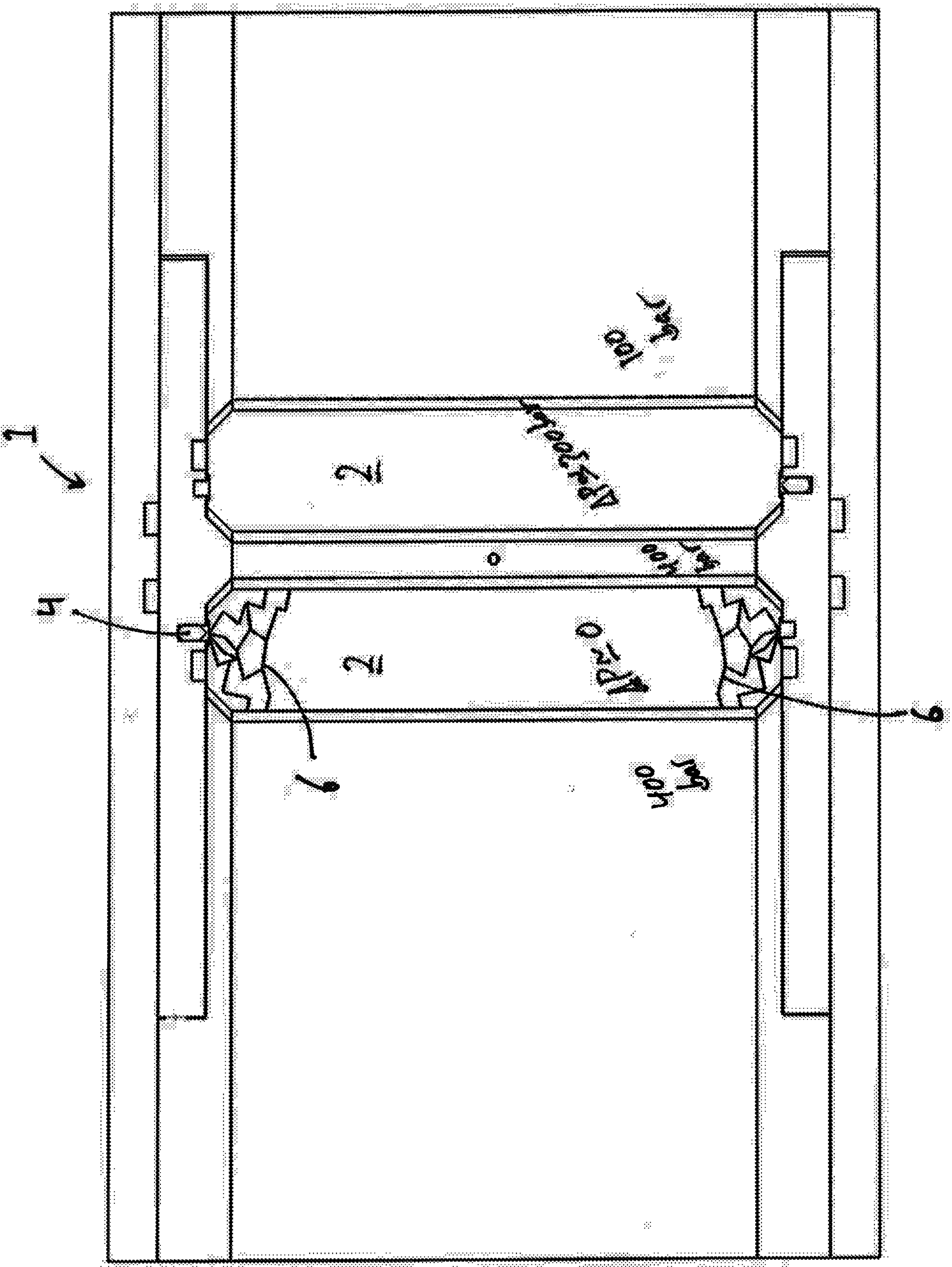


Fig. 2

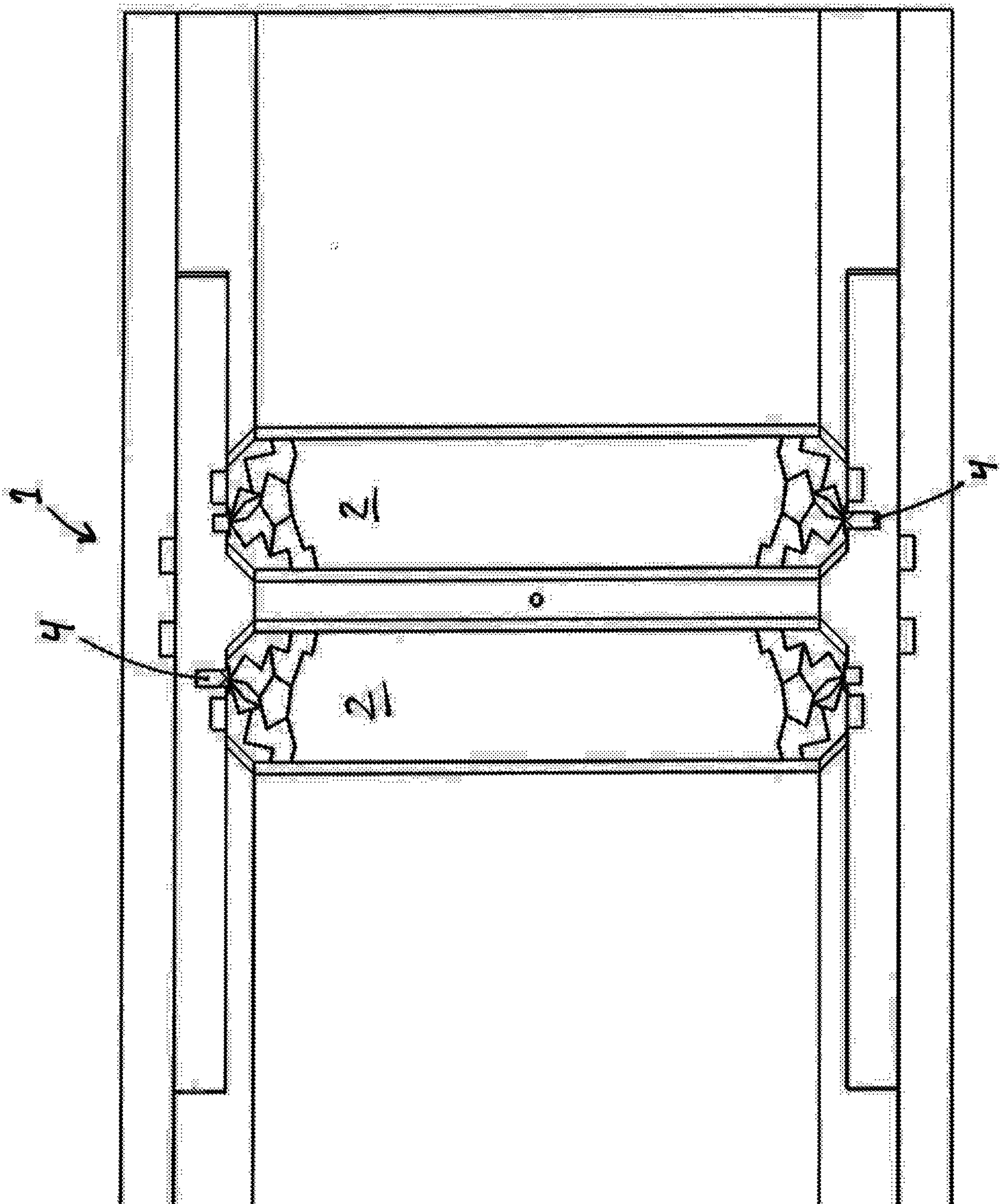


Fig.3

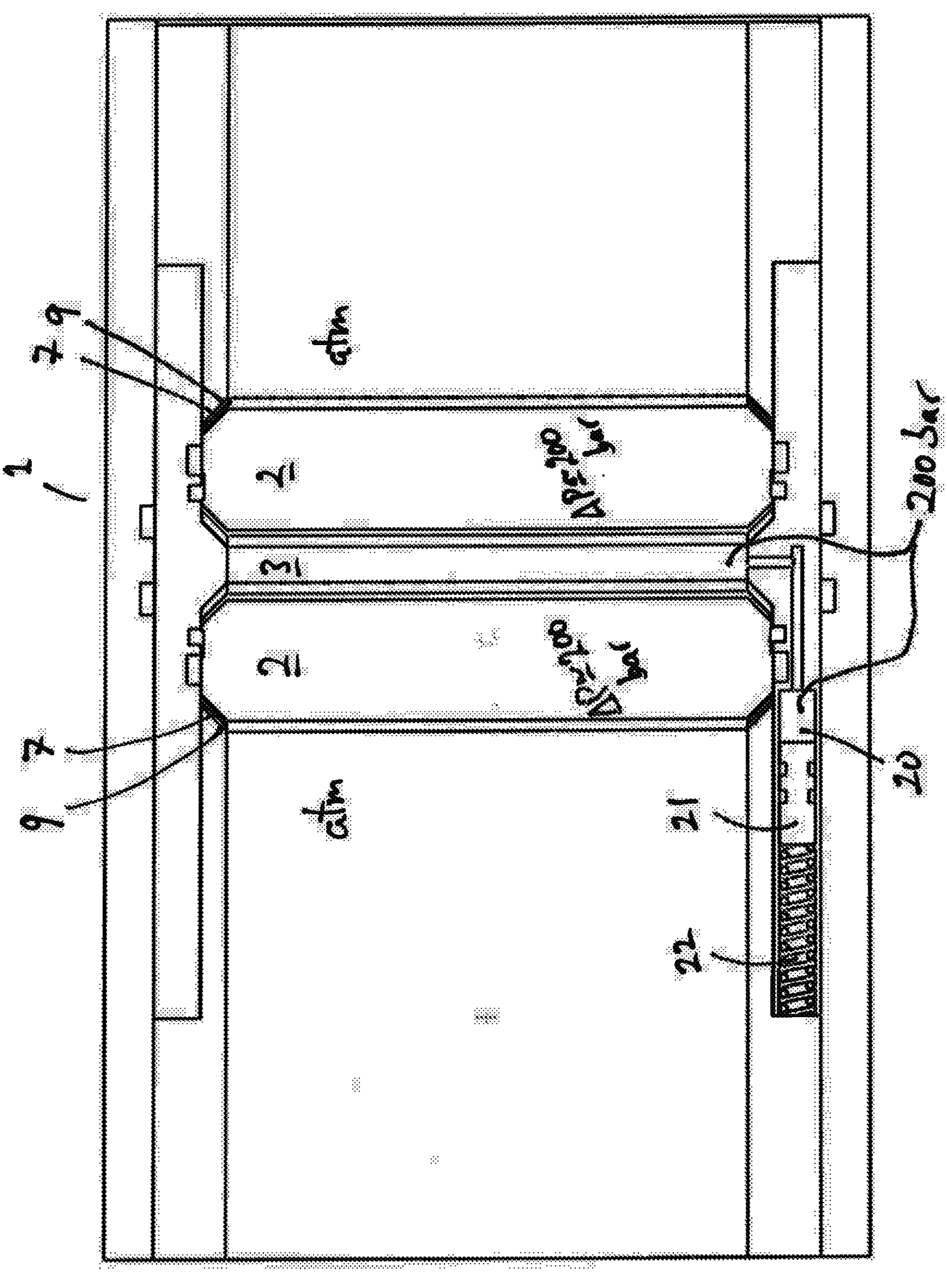


Fig. 4

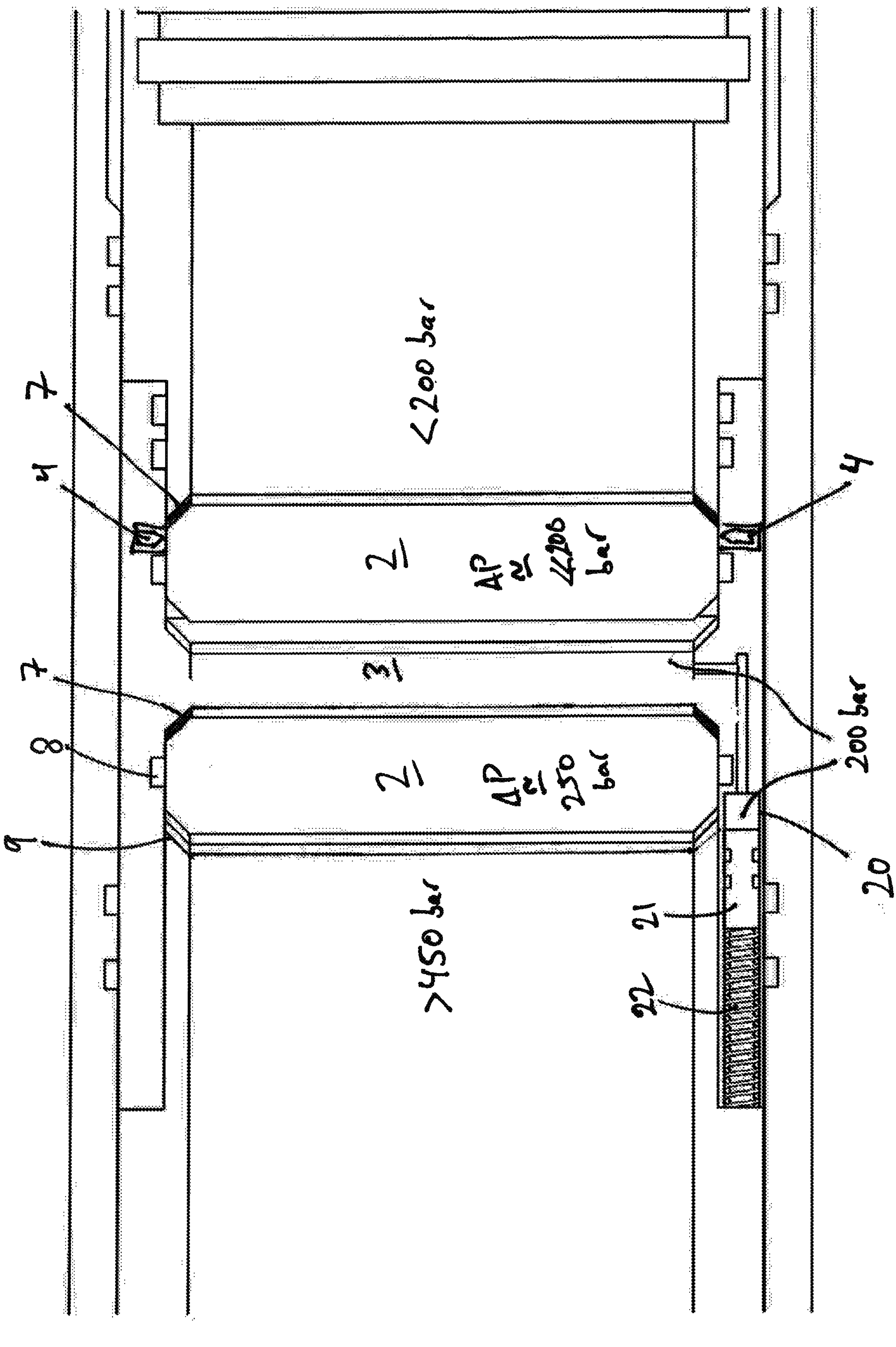


Fig. 5

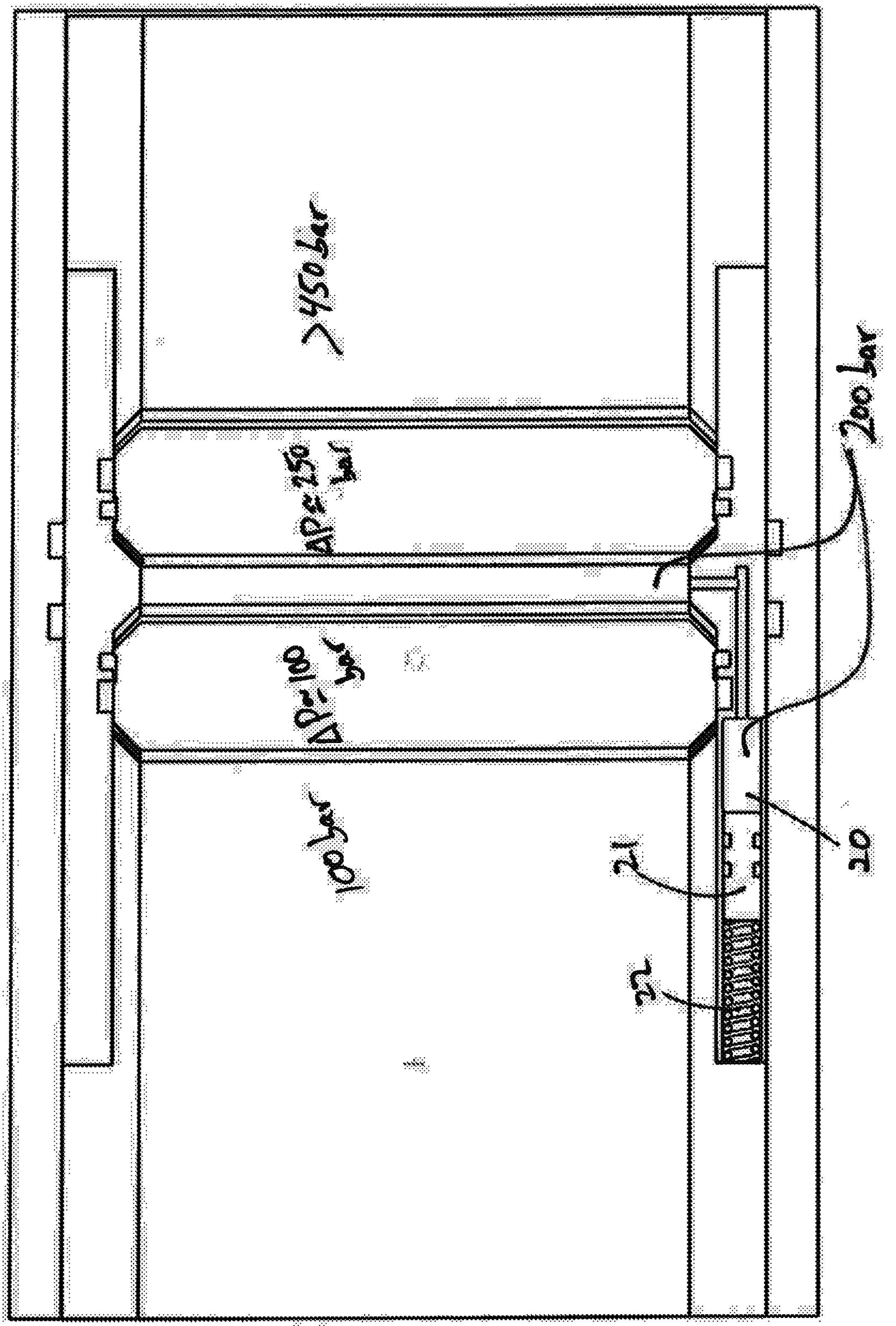


Fig. 6

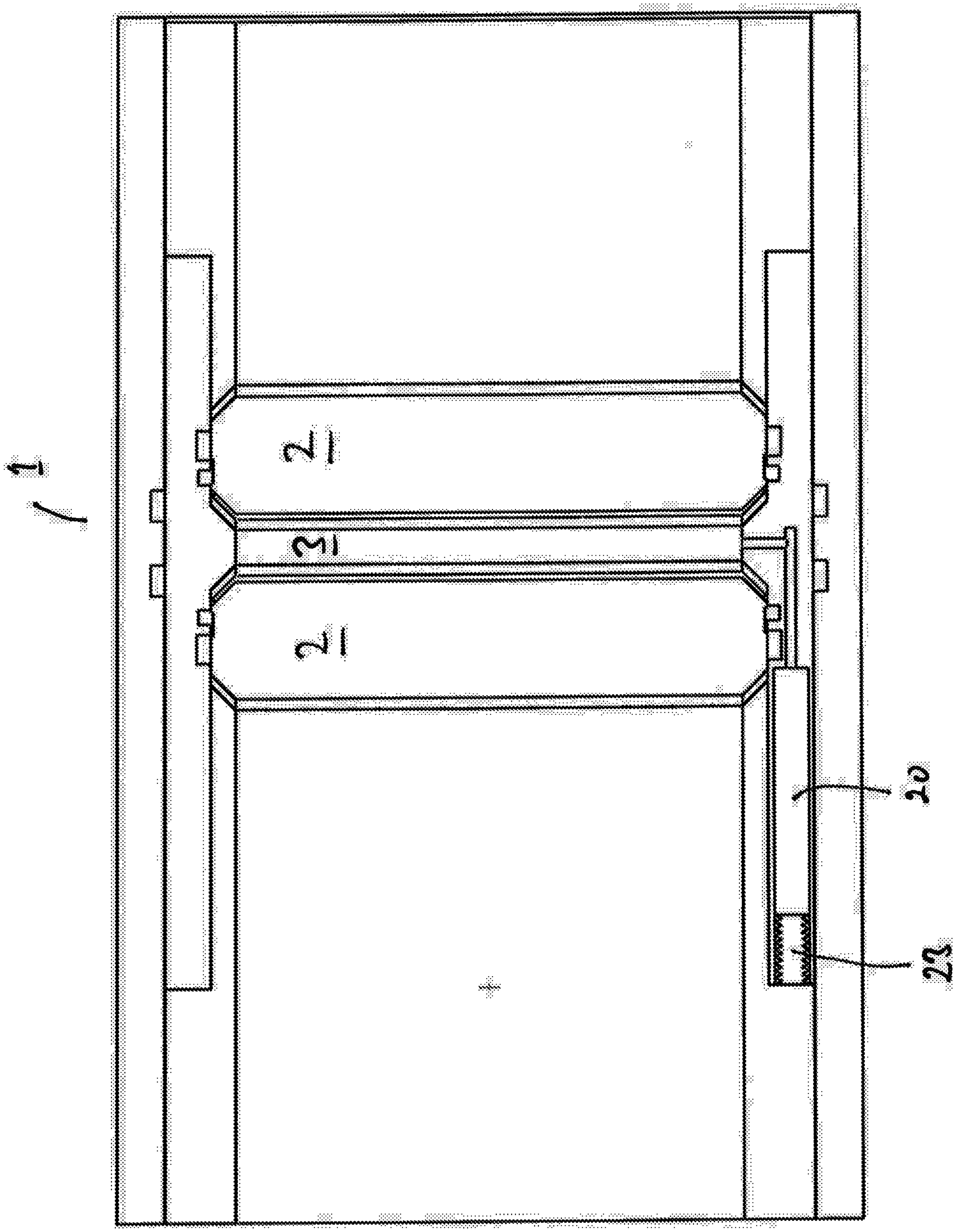


Fig. 7

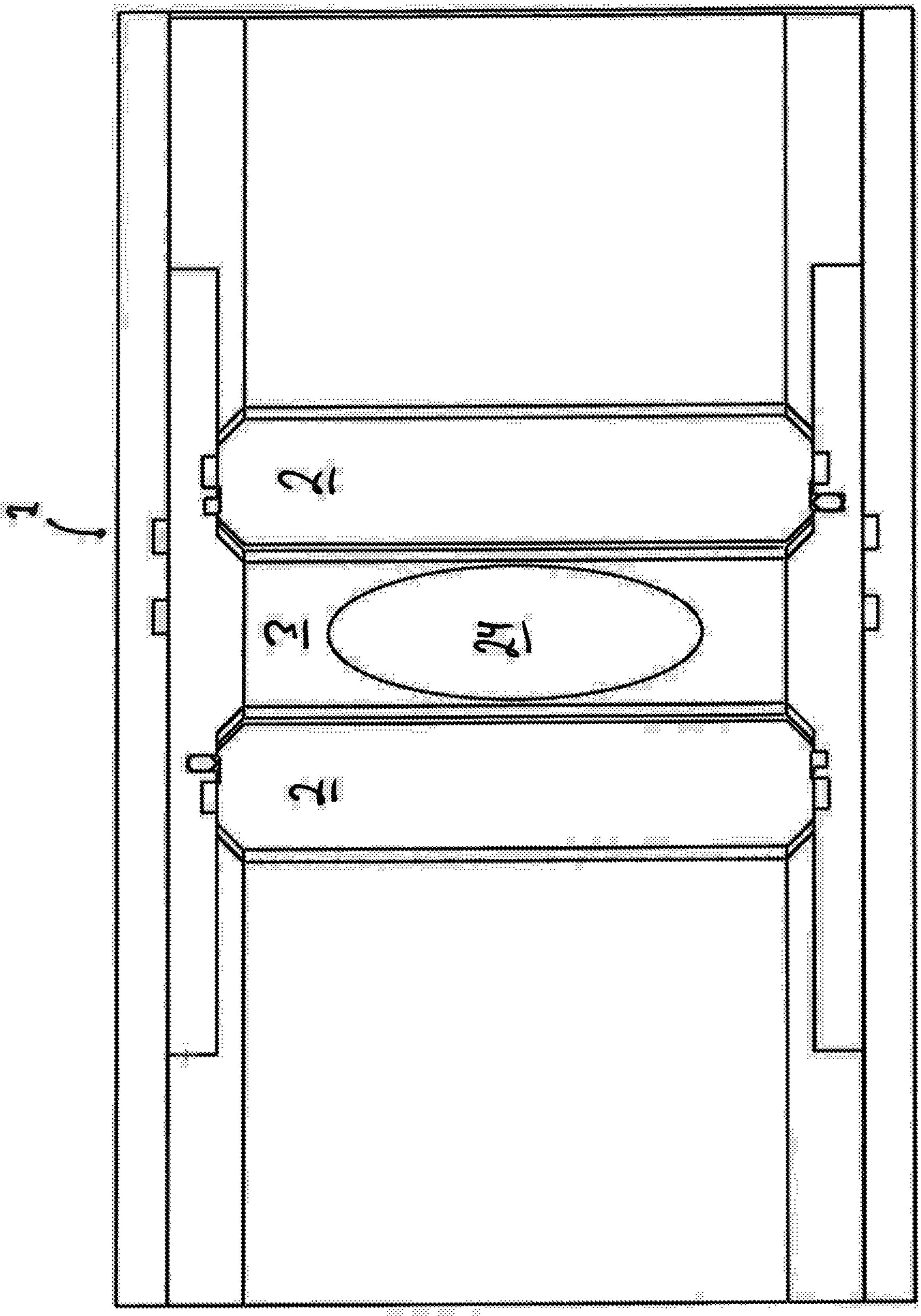


Fig. 8

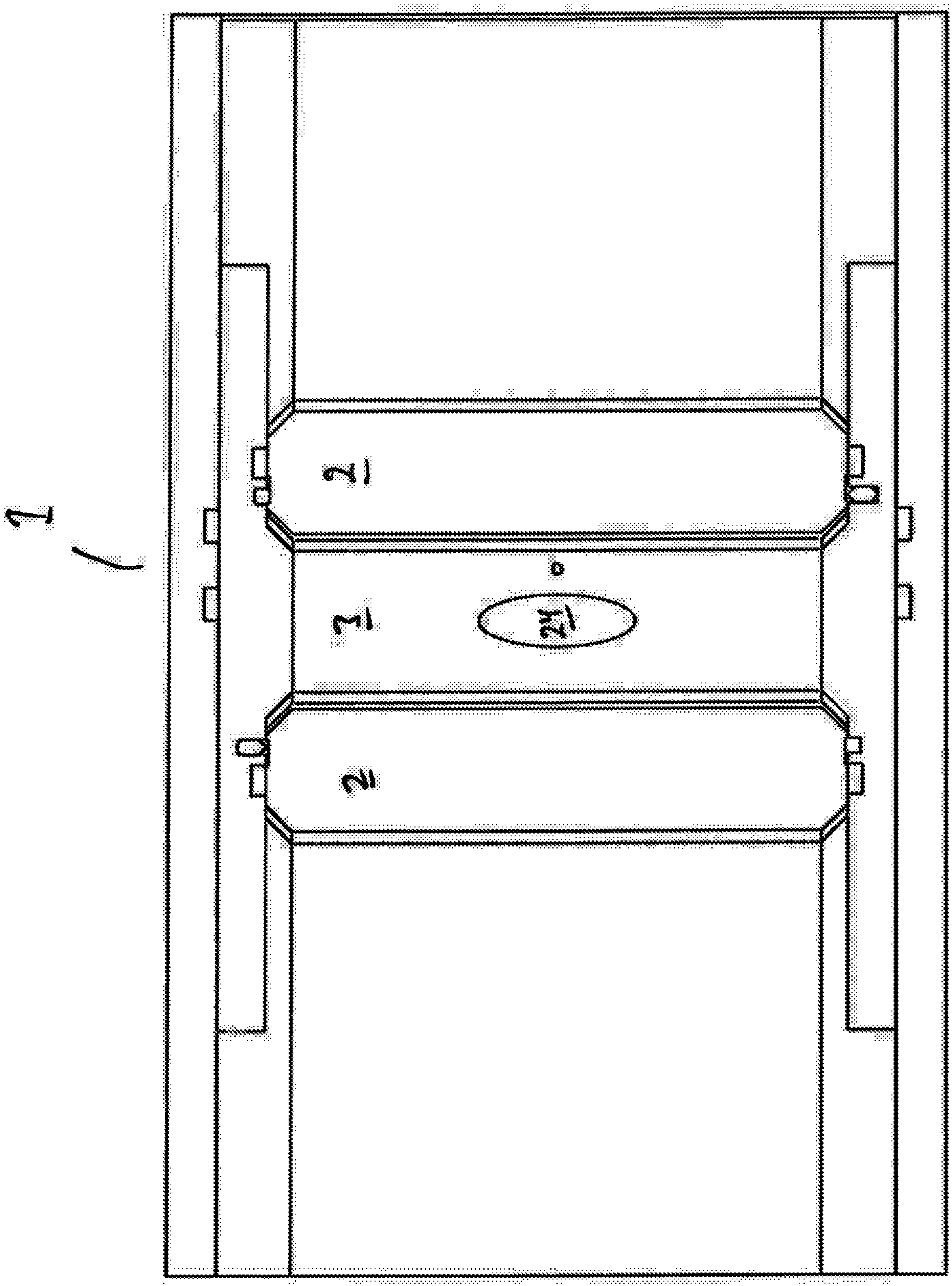


Fig. 9