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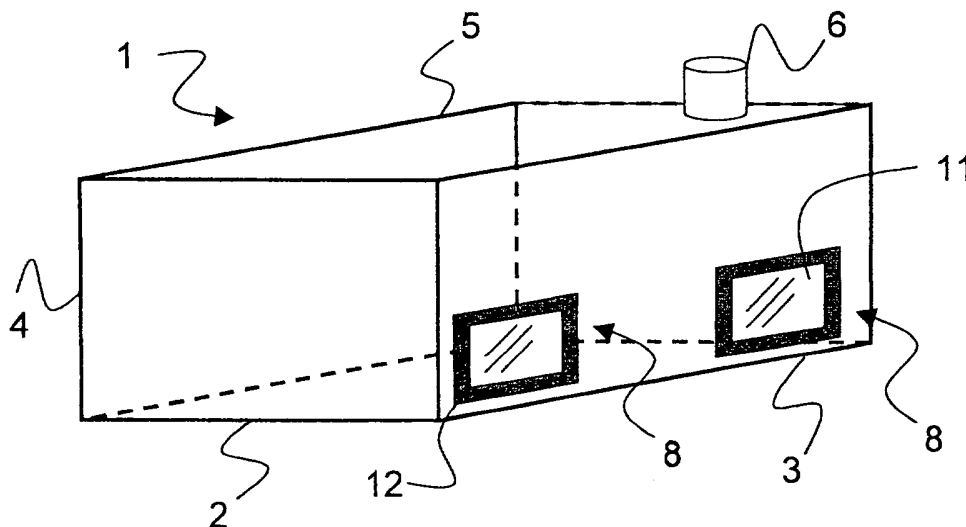
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(54) Title: CRASHWORTHINESS STRUCTURE AND METHOD



(57) Abstract: What is described is a locally yielding structure (1) with high energy absorption for aeronautical applications, the said structure being substantially closed and substantially rigid, characterized in that at least one wall (3) of the said substantially closed structure comprises at least one vent valve (8) which can be opened when a pressure exceeding a predetermined value is present within the substantially closed structure (1). In a particularly advantageous application, the invention is used in connection with a helicopter tank and enables the subfloor to be used to absorb energy by being deformed during any impact on the ground. The present invention is also advantageous for limiting the damage caused by explosions in an aircraft fuselage.

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CRASHWORTHINESS STRUCTURE AND METHOD

* * * * *

DESCRIPTION

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The present invention relates to the field of passive safety in structures, particularly aeronautical structures. Even more particularly, the present invention relates to a subfloor structure for fixed- or rotary-wing aircraft having innovative energy absorption characteristics and a new method for enhancing the passive safety of an aircraft in case of impact.

10

Research into the impact safety of aeronautical structures of helicopters and of flying machines in general originated from a series of observations and statistical analyses carried out from the 1960s and 1970s onwards. This research had the merit of demonstrating for the first time that the consequences of impacts of aircraft, particularly helicopters, on the ground could be limited, provided that action was taken to prevent clearly identified hazardous events, such as the development of fire, the penetration of large suspended masses into the cabin, the action of intense acceleration on the occupants and the intrusion of panels and other structural components into the passenger space.

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The increasingly precise identification of these events has made it possible to issue detailed military and civil specifications which have a significant effect on the design philosophy relating to the latest generation of helicopters and those of future generations. These specifications enable the nature of the problem to be defined unambiguously and clearly state the objectives to be attained.

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If the requirements of "crashworthiness" (impact safety, or more generally passive safety) are to be met, research and development

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must be broadened in scope and become more detailed, the passive safety standards themselves must be progressively improved, and there must be a radical change in design philosophy. For example, a helicopter structure can have satisfactory crash behaviour only if the passive safety specifications are analysed at the preliminary design stage.

By way of example, the total energy absorption of a helicopter is obtained not only by exploiting the contributions offered, in sequence, by the landing gear, the lower part of the fuselage ("subfloor"), the seat with its supports and the roof with the transmission support structure. This is because the satisfactory crash behaviour of each of these components considered separately is not necessarily sufficient to ensure the satisfactory behaviour of the structure considered as a whole; it is also necessary to study and optimize the behaviour of all the elements taken together. The necessity of considering different aspects of the phenomenon simultaneously has led to the identification of new design systems.

The provision of an impact-resistant ("crash-resistant") helicopter structure leads to increased costs, owing to the additional expense of a design process made more difficult by the constructional and technological complications and by the reduction of the useful volume and load capacity. On the other hand, the requirement to preserve passenger safety is of fundamental importance; it is therefore always necessary to seek structural arrangements and solutions which are efficient and effective in relation to energy absorption, and which can raise safety levels with a minimum increase in weight and cost.

Clearly, however, it is impossible to guarantee the survival of occupants in every type of accident, and therefore attention must be paid to the category of impact defined as "potentially survivable

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crashes", in which the level and duration of stresses transmitted to the passengers do not exceed the limits of human tolerance.

Research has been carried out into the acceleration which a human being can withstand in an impact, and the results have shown that a human being can withstand horizontal accelerations of up to 45 g, but
5 only for a very short period. These values decrease markedly if the acceleration acts in the vertical direction; in this case, the limit of tolerance becomes approximately 17 g for 0.04 seconds, falling to 5 g for 0.2 seconds.

10 All these data are fundamental to the design of structures capable of transmitting, in an impact, only those stresses which can be withstood by human beings, in order to ensure the survival of the latter. The object to be achieved is therefore that of designing and producing structures capable of being deformed to such an extent and in such a way as to
15 limit the levels of acceleration to which the occupants of the aircraft are subjected, while ensuring the preservation of a survival cell.

These structures must be able to absorb energy by their controlled and programmed deformation. They must also preferably be positioned in the lower part of the fuselage of the aircraft or of the helicopter, since,
20 in most cases, it is the lower part that impacts on the ground.

Among the other aspects of safety which increase the possibility of survival even after impact on the ground, the most important is unquestionably that of the prevention of fire and explosion and that of the reduction of the effects caused by these phenomena.

25 The cause of the development of a fire or an explosion in case of a crash is essentially the presence of the fuel system installed in the vehicle. The basic requirement is unquestionably the containment of the fuel. For this reason, the tanks and tubing of the fuel system must be strong and yet deformable; and they must be installed remotely from the
30 systems or elements which may initiate a fire.

The present standards require that the tank, either full-scale or on a reduced scale, or portions of it, pass drop tests without showing any leakage. Each standard stipulates the main characteristics of this test, in other words the height of fall, the degree of filling of the tank, the presence of any fittings or of the structure of the aircraft which surrounds it. For example, some standards stipulate the complete filling of the tank and a height of fall of 20 m; others require 80% filling and a height of fall of 15.2 m.

In the present state of the art, the standards are applied in the military field only; in the civil field there are no known helicopters which meet the safety requirements concerning fire prevention.

It is clear from the above that, on the one hand, it is desirable to have a highly deformable subfloor structure which can absorb some of the energy in case of impact, while, on the other hand, it is necessary to have a fuel tank (generally housed in the subfloor area, in the case of a rotating wing aircraft for example) which is not deformed, in order to avoid highly dangerous deflagration.

Similarly, although air transport is considered to be safer than ground transport (whether by road or rail), it is highly vulnerable to terrorist attack and the risk that terrorists may place an explosive device on board an aircraft is always very high. The approach followed by designers up to the present has again been that of providing increasingly stiff and strong structures which can withstand explosions which may be caused intentionally or accidentally within the fuselage, particularly in its lower part or hold.

However, this approach conflicts with the requirement to provide deformable structures which absorb some of the energy developed in case of a crash or a bomb explosion. Moreover, the stiffening of a structure causes an inevitable and undesirable increase in weight, and

in any case is generally insufficient to provide adequate protection against explosion.

US 5,451,015 relates to an aeronautical composite structure with an integral fuel tank which tackles the problem of safety in case of impact.

5 US 5,451,015 thus tackles a problem similar to that tackled by the present invention, but the solution is completely different, since, like the known solutions, it requires the stiffening of the structure.

US 4,426,050 relates to tanks which can be released in advance in case of impact.

10 In other known solutions, the fuel is discharged if the pilot foresees a potential risk of crashing.

In the light of the prior art described above, the principal object of the present invention is to provide a structure, typically of the aeronautical type, which is locally yielding with high energy absorption and which
15 also meets the requirements for passive safety of an aircraft.

A further object of the present invention is to provide a method for enhancing the passive safety of a structure, typically of the aeronautical type, with innovative and improved energy absorption characteristics.

20 A further object of the present invention is to provide a fuel tank, typically for aircraft, with innovative and improved energy absorption characteristics.

These and other objects are achieved by means of the structure and the method according to the present invention, which have the characteristics indicated in Claims 1 and 11 respectively. Further
25 advantageous characteristics of the invention are described in the corresponding dependent claims. All the claims are considered to form an integral part of the present description.

30 The fundamental principle of the present invention consists in the creation of suitably designed vent valves in the walls of a substantially closed aeronautical structure, particularly on the walls of a tank. In the

case of a fuel tank, these valves enable the fluid to be released in impact conditions and to be transferred into appropriate lateral bags (or supplementary tanks), thus enabling the subfloor to act satisfactorily as an impact absorber, while simultaneously absorbing some of the impact energy which is transferred to the fluid. In the case of a fuselage within which an explosion occurs, the vent valves allow the exit of the energy developed in the explosion and prevent the explosion from causing breaches in the fuselage itself.

Thus the present invention operates on an entirely different and opposite principle to that followed up to the present, in other words that of having very strong structures. The present invention, on the contrary, provides for substantially closed structures which, in case of an increase in pressure beyond a certain level, yield locally in predetermined positions in such a way as to reduce the pressure level.

The present invention can conveniently be associated with conventional systems, such as safety valves, which can help to contain any fire, or at least to limit its extent, by cutting off the supply to the engines and isolating the tank.

In a first aspect, the present invention provides a substantially closed structure, particularly for aeronautical applications, in which at least one of the walls of the structure comprises at least one vent valve which can be opened when the pressure inside the substantially closed structure exceeds a predetermined value, this predetermined value being at least twice (but preferably three times) the value of the normal operating pressure.

In a further aspect, the present invention provides a method for enhancing the passive safety of a substantially closed structure, particularly for aeronautical applications, comprising the step of providing, in at least one wall of the structure, at least one vent valve which can be opened when the pressure inside the substantially closed

structure exceeds a predetermined value, this predetermined value being at least twice (but preferably three times) the value of the normal operating pressure.

5 The present invention is applicable to substantially closed and substantially rigid structures for aeronautical applications, for example fuel tanks (conveniently of the helicopter type) or fuselages.

The invention will be made clear by the following detailed description, provided purely by way of example and without restrictive intent, to be read with reference to the attached sheets of illustrative drawings, in which:

- Fig. 1 shows in a highly schematic way a known tank for subfloors of aircraft, in an axonometric view;
- Fig. 2 shows a cross section through the tank of Fig. 1;
- Fig. 3 shows in a highly schematic way a tank for subfloors according to one embodiment of the present invention;
- Fig. 4 shows a cross section through the tank of Fig. 3;
- Fig. 5 shows the cross section of Fig. 4 on an enlarged scale;
- Fig. 6 shows an enlarged cross section of a tank according to the present invention with an auxiliary tank in normal conditions of use;
- Fig. 7 shows an enlarged cross section of a deformed tank with the vent valve open and the auxiliary tank full;
- Fig. 8 shows a schematic cross section of a fuselage with an energy venting device according to the present invention; and
- Fig. 9 shows the section through the fuselage of Fig. 8 in case of explosion.

By way of example, the present invention will mainly be described with reference to helicopter tanks which represent only one of a plurality of substantially closed and substantially rigid structures for aeronautical applications. For the purpose of the present invention, the

term "substantially closed structure" denotes a structure having substantially closed but not necessarily sealed structure. Thus, a substantially closed structure for aeronautical applications may be, for example, a fuel tank, a fuselage, a hold, or the like.

5 Helicopter tanks are generally positioned in subfloors, mainly because of space considerations. For their part, the subfloors act as energy absorbers in emergency situations, for example in a situation of impact on the ground, in which they absorb the energy of the impact and thus decrease the acceleration transmitted to the occupants.

10 As stated above, in some situations the tanks can therefore constitute an impediment to the performance of the functions of the subfloor, but can also cause irreparable damage if the compression of the tank causes the explosion or the uncontrolled rupture of the tank itself. In other words, the presence of fuel within the tank limits, or, if
15 the tank is full, completely compromises the required qualities of energy absorption. This is because the deformation of a tank causes the reduction of its capacity, in other words of the internal volume available to the liquid, and an increase in pressure which causes deflagration.

20 According to the present invention, suitably designed vent valves are formed in the walls of the tank. In impact conditions, these valves enable the fluid to be released from the tank and transferred to suitable lateral bags, thus enabling the subfloor to act satisfactorily as an impact absorber, while simultaneously absorbing some of the impact
25 energy which is transferred to the fluid.

It is known that there are various types of tank. In some aircraft, the structure of the fuel compartment is sealed, and this compartment acts directly as a fuel tank. However, a tank of this type frequently gives rise to sealing problems, and for this reason many aircraft use a flexible
30 bag or cell to contain the fuel. This bag is housed in the compartment.

Finally, another type of tank consists of one or more substantially flexible bags which adapt themselves to suitable empty spaces formed between the ribs and bulkheads of the aircraft.

In one aspect, the present invention provides a tank integrated into the subfloor of a helicopter, this tank being capable, even when full, of
5 maintaining its qualities of absorption of the energy arising from an impact on the ground in emergency conditions.

A preliminary study has been carried out to describe the behaviour of a tank in whose walls there have been positioned safety valves
10 which rupture when specified conditions are present, and which enable the liquid to emerge in a controlled way and thus prevent explosion.

In the first place, it was established that a tank completely filled with fuel undergoes an explosion when subjected to impact on the ground. For this purpose, use was made of a model designed for impacts at
15 50%, and this was suitably modified by filling it completely with liquid. The simulation confirmed the hypothesis of explosion: it was found that the large deformations undergone by the tank in the impact did indeed reduce the volume available to the liquid within it, and the increase in pressure caused deflagration. The hypothesis that the explosion of the
20 tank might be due to problems of instability was disproved by the fact that the hourglass energy remained at zero while the kinetic energy decreased until after the rupture of the tank.

The inventor of the present invention has realized that the pressure within a full tank can be decreased if the liquid is made to emerge from
25 the tank in a guided, controlled and predictable way and is transferred to one or more supplementary tanks connected to the main tank. This increases the volume available to the liquid, by comparison with the volume available to the liquid in the case of a tank which undergoes deformation (compression). Thus the fuel remains substantially within

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the said tank (where the expression "tank" includes the standard tank and the supplementary tank), preventing explosion.

The basic principle is therefore that of making valves open as a result of the pressure of the liquid on the walls of the tank, thus
5 permitting the fuel to flow out of the tank. For the purposes of the present invention, in Fig. 1 a conventional tank 1 is illustrated substantially in the form of a closed boxlike element, typically made from bent sheet metal and riveted at its angles (for the sake of simplicity, the stiffening and riveting are not shown). The tank 1 has a
10 base 2, four lateral walls 3, 4, and a cover 5. The tank also comprises a conventional filler tube 6. For simplicity, the illustrated tank does not include a flexible bag positioned inside the boxlike element, but the present invention is equally applicable to this type of tank. If a bag is present, a flange, entirely similar to those present in bags for other
15 purposes, is provided in the lateral wall of the substantially rigid structure of the tank for each vent valve. Fig. 2 shows a schematic cross section of the tank of Fig. 1 partially filled with liquid fuel 7.

According to the present invention, vent valves 8 have been formed in the lateral walls of the tank, forming areas of weak material and/or
20 areas which are thinner than the tank walls. Fig. 3 shows schematically two vent valves 8 in the form of apertures formed in one of the lateral walls 3 of the tank 1 and closed by breakable diaphragms.

Alternatively, it would be possible not to cut out the apertures, but simply to create an engraved area by means of a weakened profile.
25 Fig. 4 shows a cross section of the tank 1 according to the embodiment of the invention shown in Fig. 3.

Fig. 5 shows the sectional view of Fig. 1, enlarged to show the vent valve 8 more clearly. The vent valve comprises an orifice or aperture 9 formed in the wall 3 of the tank and a breakable covering diaphragm 10

fixed, for example by means of rivets 11 or the like, to the wall 3. The rivets 11 are not shown in Fig. 3.

To compensate for the loss of rigidity due to the presence of the valves, the part surrounding these is preferably reinforced by thicker elements 12 (in the form of a frame, for example).

In one embodiment of the present invention, a single break-through aperture is provided in one of the lateral walls of the tank, in a position substantially close to the base 2.

In another embodiment of the present invention, a single break-through aperture is provided in each of two or more of the lateral walls of the tank, in positions substantially close to the base 2.

In another embodiment of the present invention, at least two break-through apertures are provided in one of the lateral walls of the tank, in a position substantially close to the base 2 (Fig. 3).

In another embodiment of the present invention, at least two break-through apertures are provided in each of two or more of the lateral walls of the tank, in positions substantially close to the base 2.

The position close to the base is advantageous because it permits operation even with a small quantity of fuel. Of the various embodiments, those which are symmetrical are preferred. It should also be noted that the valves are designed in such a way that their breaking takes place not only when the tank is 100% full, but generally in all cases in which there is a certain degree of impact on the ground, and therefore also when, for example, the tank is 50% full.

The parameters to be specified for the production of the valves are therefore the size, thickness and material of the valves and their positions in terms of height and width (on which sides and on how many sides they are to be positioned); and the size, thickness and material of the reinforcing areas which are to be positioned in such a

way as to compensate for the loss of rigidity due to the presence of the valves.

By way of example, for a tank measuring approximately 1.0 m x 1.0 m x 0.5 m, made of light aluminium alloy with a wall thickness of approximately 1 mm, one solution considered acceptable is that in which four apertures measuring approximately 8-12 cm x 10-20 cm (preferably approximately 10 x 15 cm) are provided in at least one wall of the tank. Each of these apertures can conveniently be closed by a breakable membrane made from light aluminium alloy having a thickness of 0.1 - 0.3 mm, or from a plastics material such as a polycarbonate. The material to be used for the membrane in each case is a fragile or elastic-fragile material with characteristics of low plasticity.

Alternatively, as stated above, the apertures could be simply engraved into the panel of the tank, thus creating a "trigger area" (a suitably weakened wall).

It should be pointed out that the normal operating pressures within a tank for aircraft are of the order of 1-3 bars, while an explosion occurs at approximately 15-17 bars. This observation is made in order to show that there is no danger that the breakable membrane, designed to rupture at 15-17 bars, will break in normal operating conditions.

The valve is thus designed for opening at a pressure that is at least 2 times, preferably about 3 times and more preferably, more than 3 times, the pressure at nominal conditions.

Typical predetermined pressure values are 12, 13, 14, 15, 16, 17, 18, 19 or 20 bars for a fuel tank where nominal pressure is 1 – 3 bars.

According to the present invention, in the case of tanks for aircraft, particularly for helicopters, the vent valves cooperate with auxiliary chambers for containing the fuel which flows out of the said valves. In other words, the rupture of the breakable membranes (in other

words the opening of the valves 8) puts the tank into communication with the auxiliary chambers 13. In a particularly advantageous embodiment, these auxiliary chambers 13 are made in the form of bellows or the like. In a crash-free operating condition (with the tank not deformed, Fig. 6), and therefore with normal internal pressures, the valves 8 are closed and the bellows 13 are fully compacted. On the other hand (Fig. 7), if the tank is deformed (as a result of an impact) and the pressure within it increases beyond a certain limit (approximately 15 bars), the valves will rupture and the liquid will tend to flow out of the tank, thus filling the bellows, as indicated by the arrow 14. Thus the fuel will not be dispersed in a dangerous way outside the tank (in this case, the "tank" is considered to include the auxiliary tank(s) as well).

A solution similar to that applied and described in detail for an aeronautical tank, particularly of the helicopter type, can also be used as an energy release mechanism in case of the explosion of an explosive device in a hold of a commercial or military fixed-wing aircraft. Accordingly, the present invention provides for the discharge of the energy to the outside, by contrast with known solutions in which the objective has been to "contain" the explosion.

Fig. 8 shows schematically a section of fuselage 20. According to the present invention, vent valves 8, entirely similar to those described and illustrated with reference to fuel tanks, are provided in the base of this fuselage. If an explosion occurs, the energy which is developed can be released through the valves 8 and will not cause tears or other damage to the fuselage. If the present invention is applied to a fuselage (particularly to the hold) of an aircraft, it will clearly not be necessary to provide auxiliary chambers to enhance the explosion-proofing (by contrast with the application to fuel tanks).

Clearly, therefore, in the light of the above description, the present invention can be applied in various ways. It can be used in subfloor tanks and baggage compartment structures (in fixed- and moving-wing aircraft), these structures being new or already in use and suitably
5 modified.

The present invention can be subjected to numerous modifications, adaptations and replacement of parts with other functionally equivalent parts. All such modifications, adaptations and replacement of parts are considered to fall within the scope of protection of the present
10 invention, which is limited only by the attached claims.

CLAIMS

1. Locally yielding structure with high energy absorption for aeronautical applications, the said structure being substantially closed and substantially rigid, characterized in that at least one
5 wall of the said substantially closed structure comprises at least one vent valve which can be opened when a pressure exceeding a predetermined value is present within the substantially closed structure.
2. Structure according to Claim 1, characterized in that the said vent
10 valve comprises a breakable membrane.
3. Structure according to Claim 2, characterized in that the said breakable membrane is positioned to close a corresponding aperture.
4. Structure according to Claim 1, 2 or 3, characterized in that the
15 said vent valve comprises an aperture stiffening device.
5. Structure according to Claims 2 to 4, characterized in that the said breakable membrane comprises a metallic or plastics material which is substantially fragile or elastic-fragile.
6. Structure according to any one of Claims 1, 2, 4 and 5,
20 characterized in that the said vent valve comprises an engraved area which forms a weakening in the said at least one wall, the said engraved area acting as a trigger area.
7. Structure according to any one of the preceding claims, characterized in that it is a subfloor structure of an aircraft.
- 25 8. Structure according to Claim 7, in which the said structure is a tank, characterized in that it comprises at least one supplementary tank cooperating with the said at least one vent valve.
9. Structure according to Claim 8, characterized in that the said at least one supplementary tank is compacted in its unused state, in

other words with the vent valve closed, and expanded when the vent valve is open.

- 5
10. Structure according to any of the preceding claims, characterized in that said pressure predetermined value is at least 3 times the pressure value within the structure at nominal conditions of operations.
11. Structure according to claim 10, characterized in that said pressure predetermined value is at least 15 bars.
12. Structure according to any one of Claims 1 to 6, characterized in that it is an aircraft fuselage structure.
- 10
13. Method for enhancing the passive safety of a substantially closed and substantially rigid structure, in particular a structure for aeronautical applications, characterized by the step of providing at least one vent valve which can be opened when a pressure exceeding a predetermined value is present within the substantially closed structure.
- 15
14. Method according to Claim 13, characterized in that the said step of providing a vent valve comprises the step of providing a breakable membrane.
- 20
15. Method according to Claim 14, characterized in that the said step of providing a breakable membrane comprises the step of positioning a breakable membrane to close a corresponding aperture.
- 25
16. Method according to any one of Claims 13 to 15, characterized in that an aperture stiffening device is provided.
17. Method according to Claim 14, 15 or 16, characterized in that the step of providing a breakable membrane comprises the step of providing a substantially fragile or elastic-fragile membrane made from a metallic or plastics material.

18. Method according to any one of Claims 13 to 17, characterized in that the step of providing a vent valve comprises the step of providing an engraved area which forms a weakening in the said at least one wall, the said engraved area acting as a trigger area.
- 5 19. Method according to any one of Claims 13 to 18, characterized in that the said structure is a subfloor structure of an aircraft.
20. Method according to Claim 19, in which the said structure is a tank, characterized in that at least one supplementary tank, interacting with the said at least one vent valve, is provided.
- 10 21. Method according to any one of Claims 13 to 20, characterized in that the step of opening the said at least one vent valve comprises the step of opening this valve in the presence of a pressure which is at least twice, but preferably three times, the normal operating pressure in the said substantially closed structure.
- 15 22. Method according to claim 20, characterized in that said step of opening the said at least one vent valve comprises the step of opening this valve at a pressure equal to, or higher than, about 15 bars.

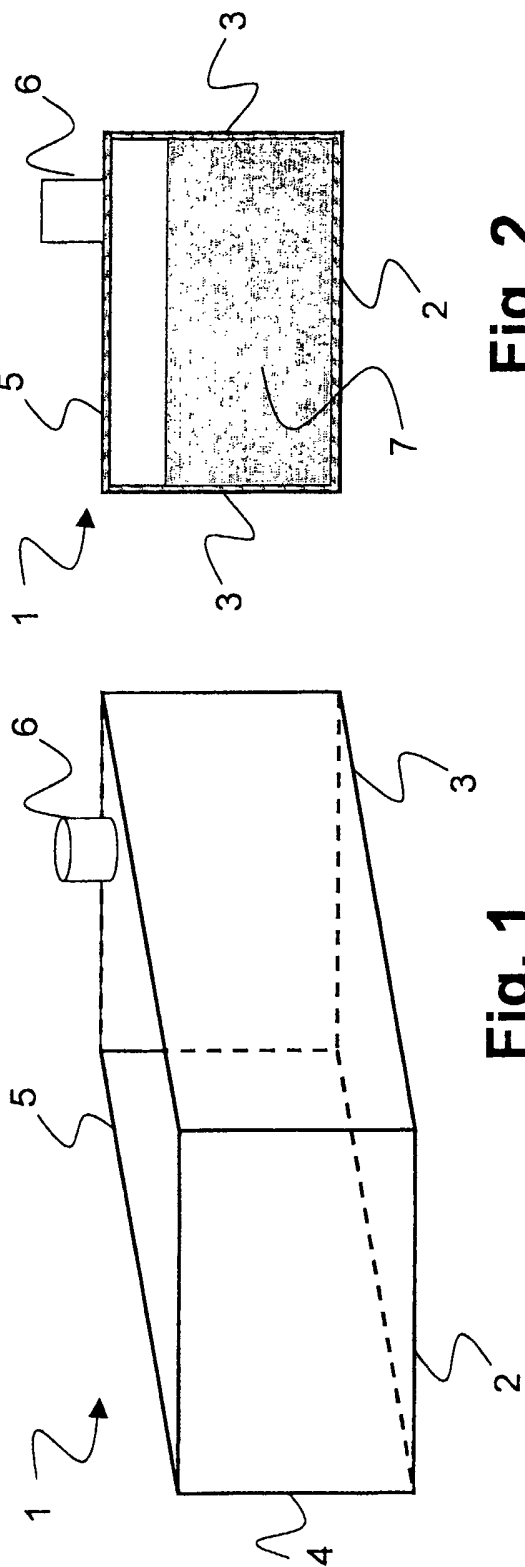


Fig. 1

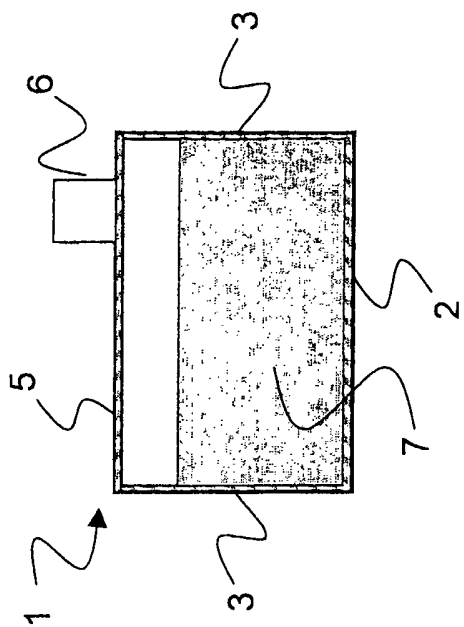


Fig. 2

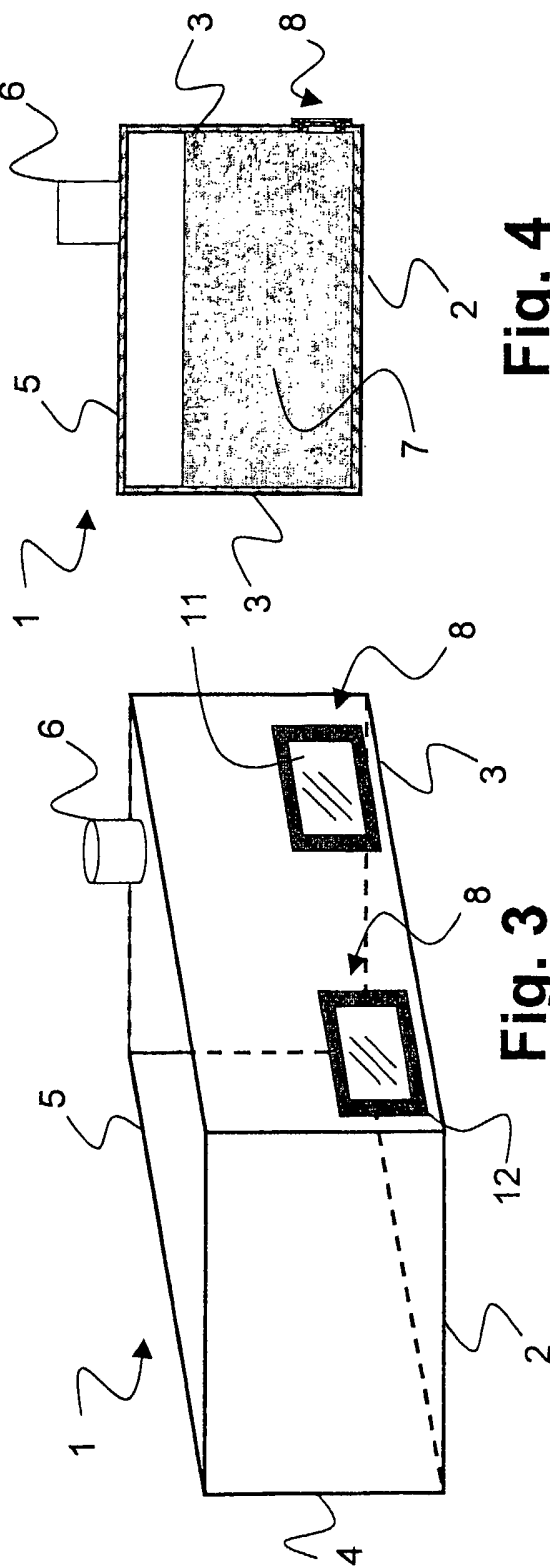


Fig. 3

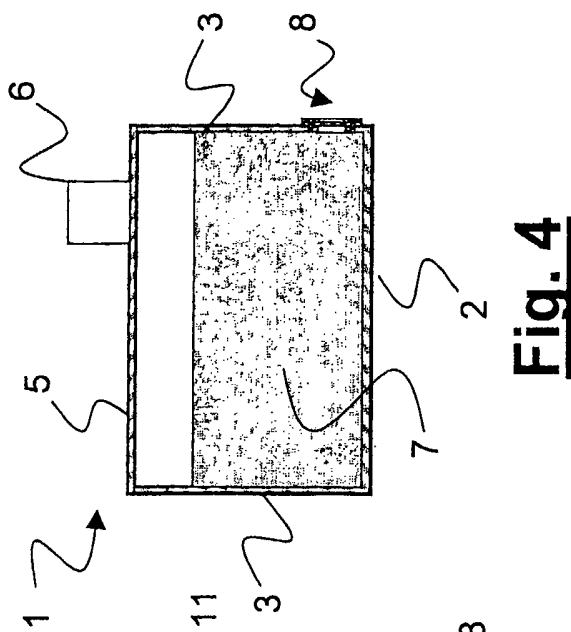


Fig. 4

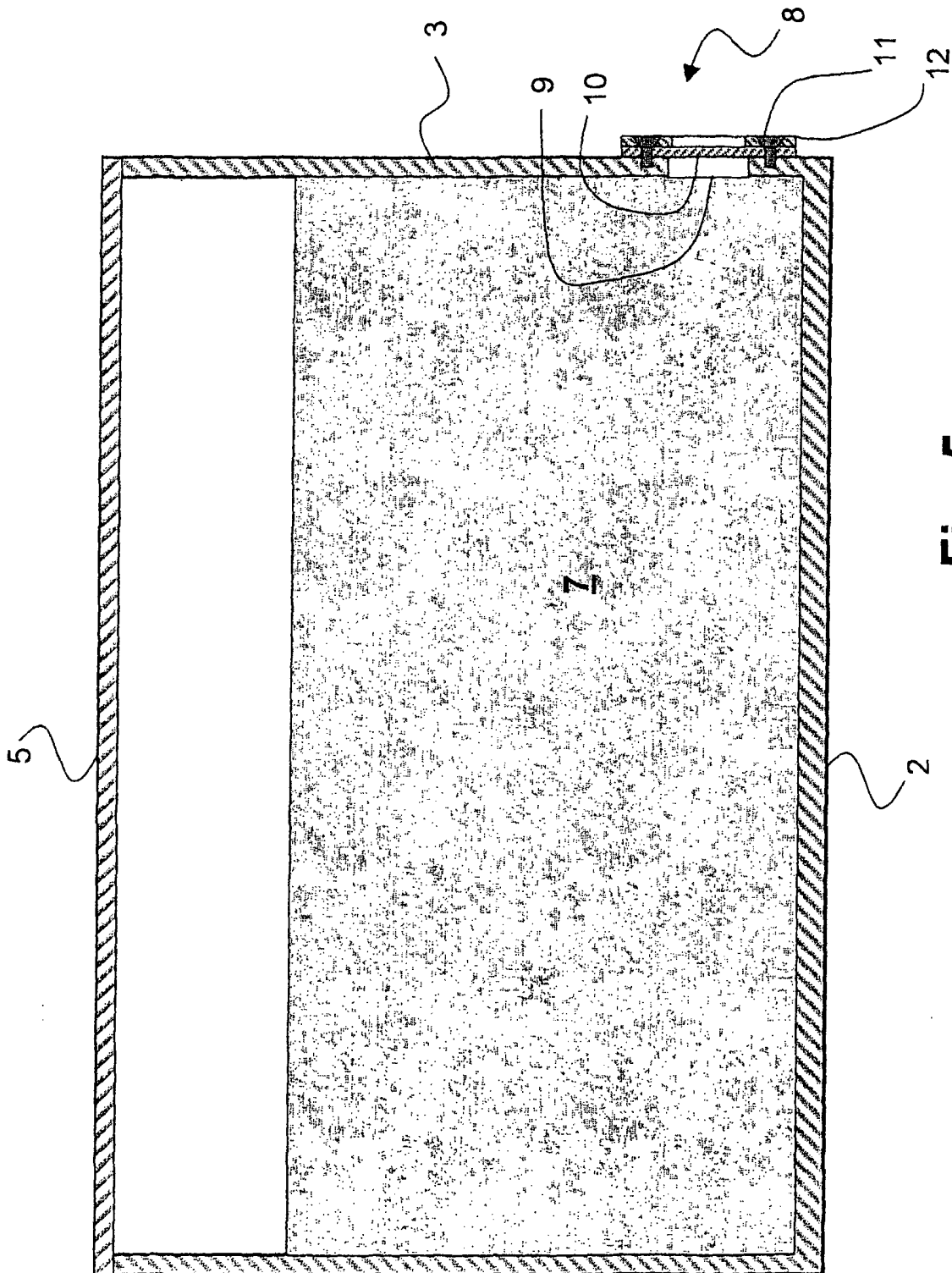


Fig. 5

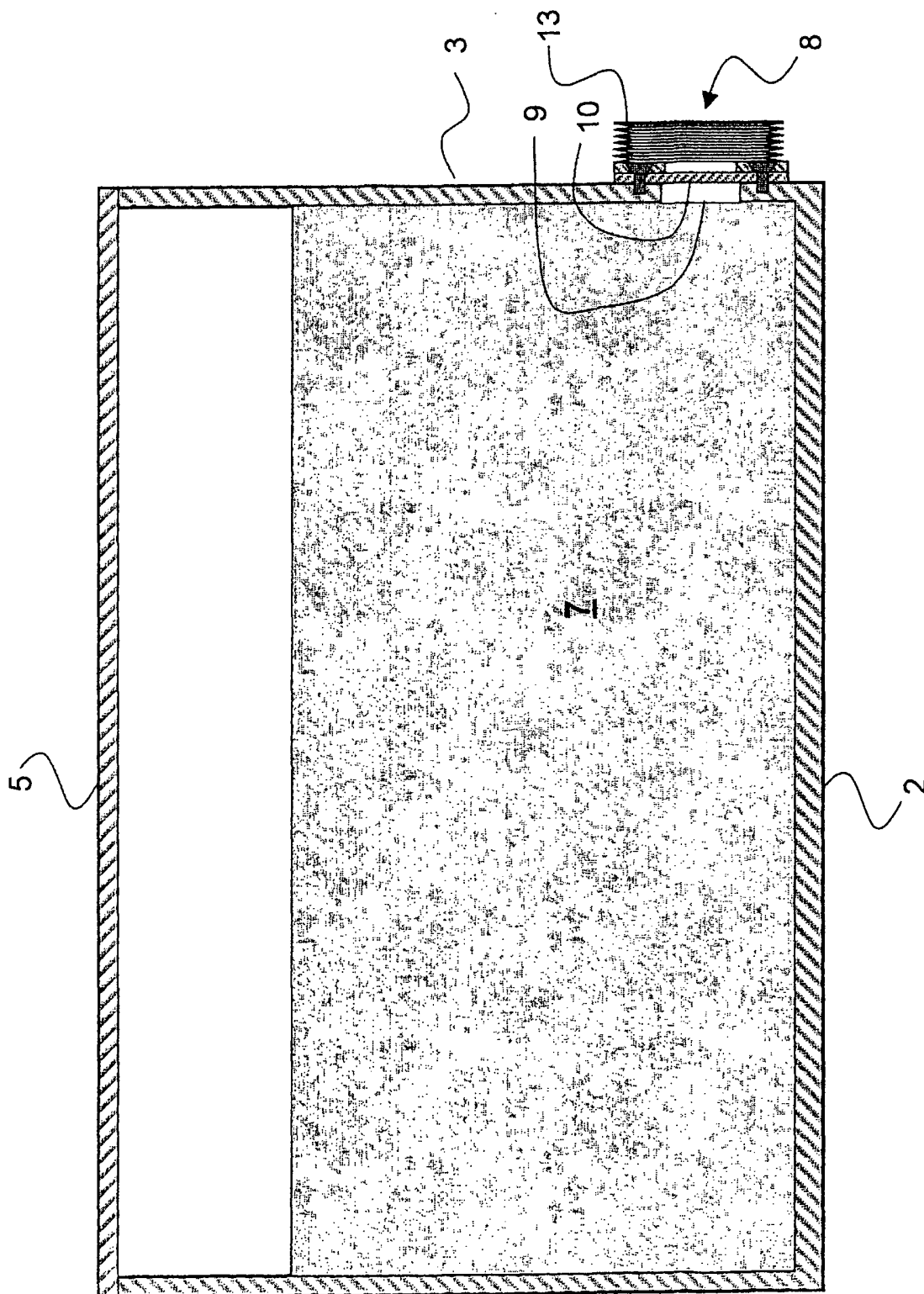


Fig. 6

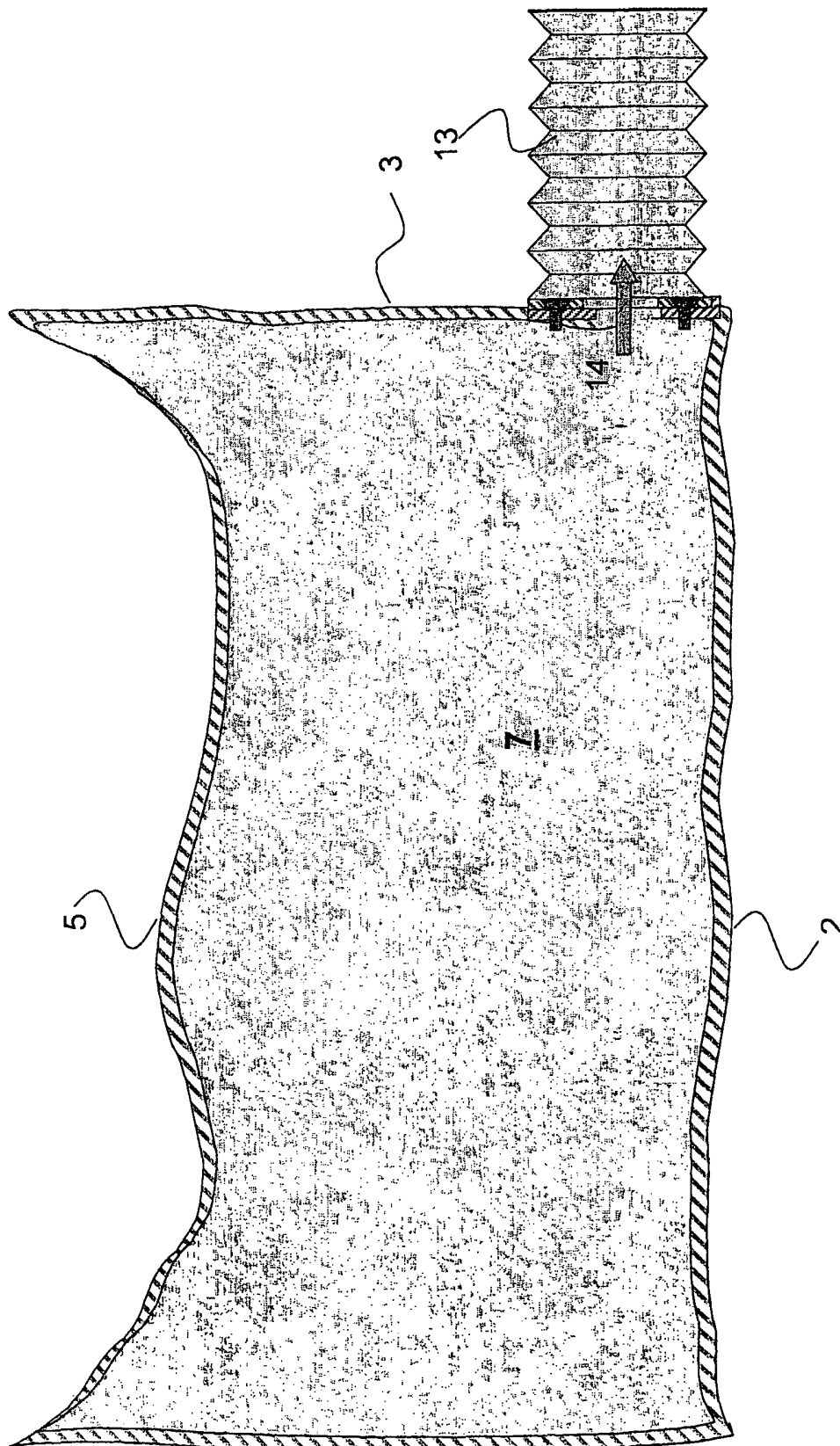


Fig. 7

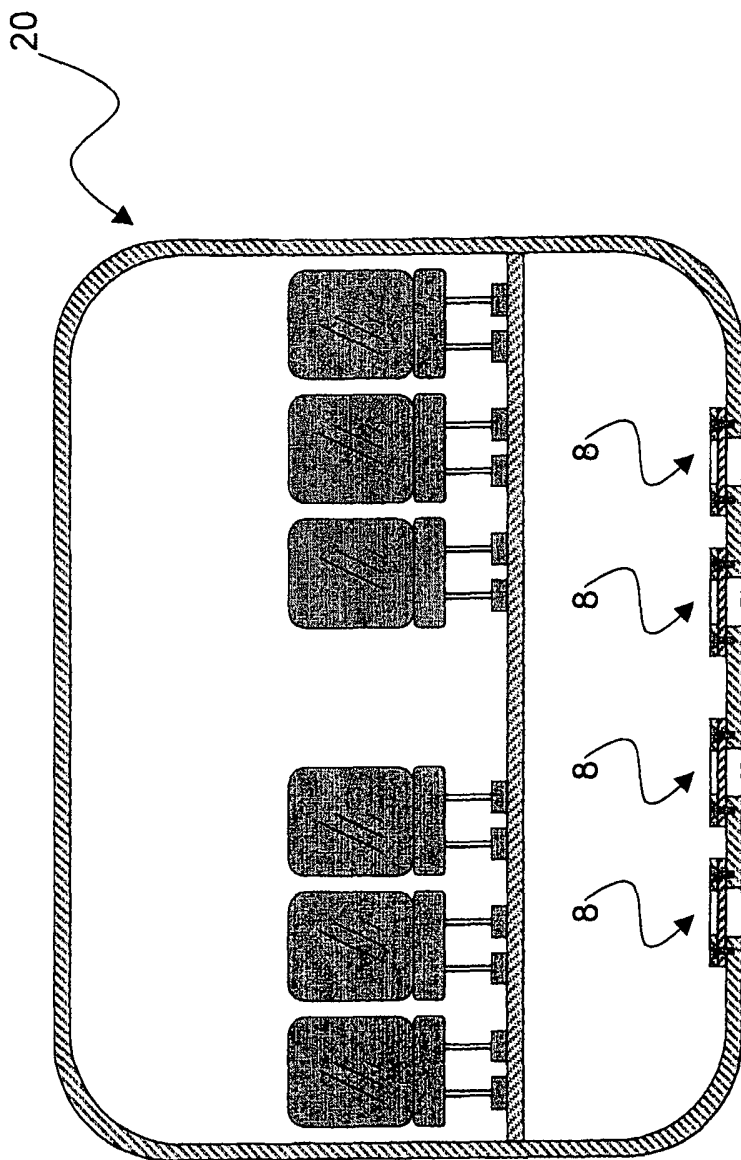


Fig. 8

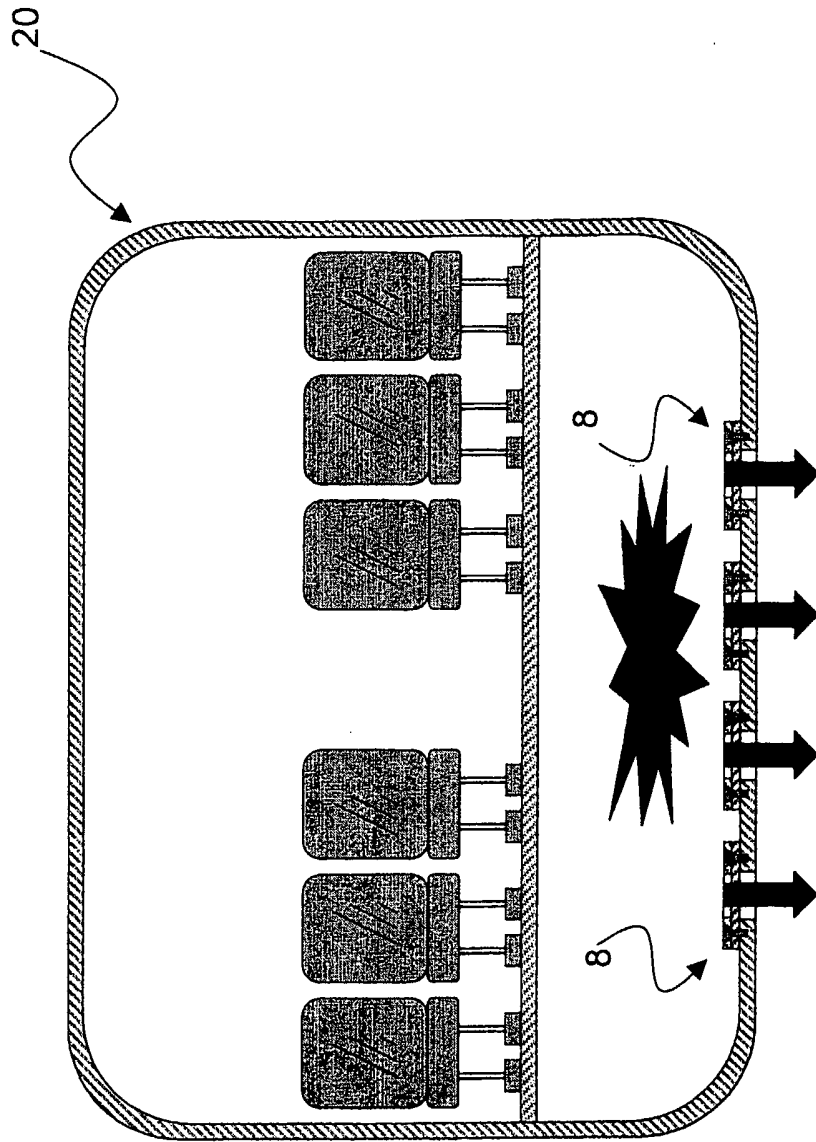


Fig. 9

INTERNATIONAL SEARCH REPORT

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER
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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Further documents are listed in the continuation of box C. Patent family members are listed in annex.

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

Date of the actual completion of the international search 21 September 2004	Date of mailing of the international search report 27/09/2004
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Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Estrela y Calpe, J
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INTERNATIONAL SEARCH REPORT

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