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(54) Benævnelse: **Indretning til dæmpning af en fluid i en beholder, især i et rumfartøj**

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DEVICE FOR DAMPING FLUID IN A RESERVOIR, IN PARTICULAR OF A SPACECRAFT

TECHNICAL FIELD

[0001] The present invention relates to a device for damping a fluid contained in a reservoir.

PRIOR ART

[0002] Although not being exclusive, the present invention applies more particularly to a reservoir of a spacecraft.

[0003] The flight of a spacecraft, such as a rocket or a launcher, is composed of several phases, and ends with the release and deployment of a payload, in particular a satellite. In general, the spacecraft comprises a plurality of successive stages. Each of these stages is provided with a rocket engine whose fuel is a propergol propellant, i.e. a mixture of several ergol propellants contained in several reservoirs arranged in each stage.

[0004] The movement of the spacecraft, during each of these phases, is ensured by the combustion of the propergol propellant in the rocket engine of one stage. When all the propergol propellant of one stage has been consumed, the corresponding stage separates from the spacecraft which then begins a new flight phase thanks to the combustion of the propergol propellant contained in the reservoirs of the next stage.

[0005] In particular, the payload is usually located in the last stage, called the upper stage of the spacecraft. The propergol propellant used in the rocket engine of the upper stage comprises two cryogenic ergol propellants, namely, liquid oxygen and liquid hydrogen. These two cryogenic ergol propellants are kept in the liquid state in two separate reservoirs arranged on top of one another in the upper stage.

[0006] During the flight phases preceding the deployment of the payload, the manoeuvres of the spacecraft performed under microgravity or low-gravity could generate large movements of the liquid ergol propellants in their reservoirs. These movements are more significant for liquid hydrogen because it is a low-density fluid. Although the reservoirs are cooled down in order to keep the ergol propellants in their liquid phase, they may comprise areas whose temperature is higher than the critical vaporisation temperature. Yet, one manoeuvre could cause an uncontrolled movement of the liquid hydrogen, such as rocking movements. The liquid hydrogen then vaporises on contact with these hotter areas. The products generated by the evaporation should then be evacuated out of the reservoir. This reduction in the amount of liquid hydrogen and therefore of propergol propellant that can be used by the engine results in a loss of performance of the spacecraft. This loss of performance is reflected by a decrease in the amount of liquid hydrogen which could reach several hundred kilograms.

[0007] Most of the systems aiming to overcome the problem of the vaporisation of the ergol propellants on the hot areas of the reservoirs seek to minimise the surface in contact between the liquid hydrogen and the hot areas of the reservoirs. Yet, such systems are expensive. In addition, they considerably weigh down the upper stage, yet without guaranteeing the actual amount of liquid hydrogen that can be used.

[0008] Hence, these current systems are not completely satisfactory.

[0009] Moreover, the document US5901557 discloses a reservoir for a spacecraft intended to store a pressurised cryogenic fluid under microgravity conditions. This reservoir is equipped with a system allowing extracting only the liquid phase from the reservoir. In particular, this system comprises a net arranged on a rigid framework comprising rods and rings so as to be able to be crossed by a liquid and to reduce flow speeds.

DISCLOSURE OF THE INVENTION

[0010] The present invention aims to overcome this drawback. To do so, t relates to a device for damping a fluid intended for a reservoir, in particular of a spacecraft.

[0011] According to the invention, said device includes a framework provided with at least one ring and a plurality of rods, each of said rods being fastened by a first end around said ring, said device including a net arranged on the plurality of rods and around the ring, the net comprising a mesh adapted to the viscosity of the fluid (to be damped) so as to damp movements of said fluid, said device further including a plurality of holding elements, each of the rods being arranged in a holding element by a second end opposite to the first end.

[0012] Thus, thanks to the invention, a net fastened on a rigid framework is used which dampens the rocking movements of a fluid. In addition, the flexibility of the net allows achieving this result without generating splashing phenomena, as indicated hereinafter.

[0013] In addition, the device is configured to be able to be brought from a folded position into an unfolded position, the folded position corresponding to a position of the device in which the rods are arranged substantially parallel to each other and each of said rods forms a zero angle with a so-called longitudinal axis of said device, the unfolded position corresponding to a position of the device in which the rods are not parallel to each other and each of said rods forms an angle called deployment angle, said deployment angle being non-zero with the longitudinal axis.

[0014] Moreover, advantageously, each of the holding elements is intended to be fastened on a part and to hold the device at least in the unfolded position.

[0015] Furthermore, preferably, each of the holding elements includes a locking system capable of locking the rods in a position corresponding to an unfolded position of the device.

[0016] Moreover, advantageously, the value of the deployment angle between said rods and the longitudinal axis of the device depends on a porosity parameter of the mesh of the net.

[0017] Preferably, the porosity parameter is comprised between 0.3 and 0.5.

[0018] Furthermore, preferably, the ring is extensible in a so-called radial direction and configured to be able to be brought from a first state when the device is in the folded position to a second state when the device is in the unfolded position, the size of said ring in said first state being smaller than the size of said ring in said second state.

[0019] Moreover, advantageously, the rods are distributed at regular angular intervals around the ring.

[0020] Furthermore, the rods are made of an aluminium alloy. The use of aluminium rods allows not weighing down the device.

[0021] In addition, advantageously, the net is made of a polymer material. The use of a polymer material allows obtaining a net that is both flexible and light. The flexibility of the net allows damping or stopping the rocking movements of the fluid, in particular without generating splashes.

[0022] The present invention also relates to a reservoir, in particular for a spacecraft, comprising a fluid damping device such as that one described hereinabove.

[0023] Moreover, advantageously, the reservoir comprises a part arranged in a lower portion, said part being configured to fasten the device on said reservoir, said part being removable.

[0024] In addition, the present invention relates to a spacecraft comprising a reservoir such as that one described hereinabove.

BRIEF DESCRIPTION OF THE FIGURES

[0025] The appended figures will facilitate understanding of how the invention could be implemented. In these figures, identical references refer to similar elements.

-[Fig 1] Figure 1 is a schematic perspective view of a fluid damping device, in a first configuration, in a reservoir, according to a preferred embodiment.

-[Fig 2] Figure 2 is a schematic perspective view of a fluid damping device, in a second configuration, in a reservoir, according to the preferred embodiment.

-[Fig 3] Figure 3 illustrates a portion of a fluid damping device in the first configuration.

-[Fig 4] Figure 4 illustrates the same portion of the fluid damping device in the second configuration.

-[Fig 5-6] Figure 5 illustrates another portion of the fluid damping device, according to a particular embodiment and Figure 6 illustrates a fluid damping device in the second configuration, according to a particular embodiment.

DETAILED DESCRIPTION

[0026] The fluid damping device 1 (hereinafter “device 1”), schematically shown in a particular embodiment in Figure 1 and allowing illustrating the invention, is intended to allow damping a fluid in a reservoir 6. Preferably, this fluid is liquid hydrogen present in the reservoir 6 of a spacecraft, wherein the stage 11 comprising the reservoir 6 is shown very schematically in Figure 1.

[0027] In the context of the invention, this device 1 comprises, as shown in Figures 1 and 2, a net 2, a framework 3 on which the net 2 is arranged and a plurality of holding elements 4. The holding elements 4 are capable of holding the net 2 and the framework 3 in a fixed position on a part 5 of the reservoir 6, in particular during the flight of the spacecraft in the case of a reservoir 6 of a spacecraft.

[0028] In the following description and as shown in Figures 3 and 4, a reference frame R is used associated with the device 1 and defined according to three orthogonal axes, namely a so-called longitudinal axis X which is oriented along the device 1, and two medial Y and transverse Z axes which define a transverse plane YZ. In addition, the adjectives “upper” and “lower” with respect to the device 1 or to the reservoir 6 are defined according to the direction of an arrow F and the opposite direction of the arrow F respectively.

[0029] As shown in Figures 3 and 4 in particular, the framework 3 include a plurality of rods 7 and at least one ring 8 arranged in the upper portion of the device 1 (hereinafter “upper ring 8”).

[0030] In a preferred embodiment, the upper ring 8 has a circular shape with a centre O belonging to the longitudinal axis X. In addition, the upper ring 8 is arranged in a transverse plane YZ perpendicular to the longitudinal axis X In this preferred embodiment, the upper ring 8 is extensible in a radial direction perpendicular to the longitudinal axis X, as shown by arrows E. For example, the upper ring 8 is a spring.

[0031] The upper ring 8 may be brought from a first state, as shown in Figure 4, to a second state, as shown in Figure 3. The size of the upper ring 8 in the first state is smaller than the size of the upper ring 8 in the second state.

[0032] Moreover, the rods 7 are arranged around the upper ring 8. In a particular embodiment, the framework 3 includes eight rods 7.

[0033] Preferably, these rods 7 are made of aluminium. The use of rods 7 made of aluminium allows not weighing down the framework 3, which increases the performances of the spacecraft during its flight.

[0034] In a preferred embodiment, each of the rods 7 of the framework 3 is provided with an end 9A by which it is fastened to the upper ring 8. As shown in Figure 3, the ends 9A of two of the adjacent rods 7 around the upper ring 8 form, with the longitudinal axis X, an angle α. The rods 7 are arranged around the upper ring 8 at substantially equal angles α. In addition, each of the rods 7 is arranged in a radial plane defined by the longitudinal axis X and an arrow E.

[0035] In this preferred embodiment, each of the rods 7 also comprises an end 9B, opposite to the end 9A. The rods 7 are arranged individually, by their ends 9B, in holding elements 4. The number of rods 7 is identical to the number of holding elements 4. Only one of the rods 7 is associated with only one of the holding elements 4.

[0036] In a particular embodiment, shown in Figures 3, 4 and 6, the framework 3 further includes a ring 10 arranged in a lower portion of the framework 3. This so-called lower ring 10 is fastened on an area of each of the rods 7 close to their second ends 9B. In addition, the lower ring 10 is rigid. Its size is identical to the size of the upper ring 8 when the upper ring 8 is in the first state, as shown in Figure 4.

[0037] Moreover, as shown in Figures 1, 2 and 5, the holding elements 4 are fastened to the part 5 with a circular section. In a particular embodiment, this part 5 is a removable element arranged in a lower portion of the reservoir 6. The device 1 is then rigidly fastened to the reservoir 6. For example, a part 5 on which the holding elements 4 are fastened is an access door to the reservoir 6 by a lower end.

[0038] Furthermore, the holding elements 4 are arranged in a circle on the edge of the part 5. The circle is centred around the longitudinal axis X. The size of the circle formed by the holding elements 4 is substantially equal to the size of the upper ring 8 when it is in the first state.

[0039] In a preferred embodiment, a particular rod 7 and a particular holding element 4, in which it is arranged, form a pivot connection (not shown). This pivot connection makes the rod 7 capable of performing rotational movements about a tangential axis perpendicular to the longitudinal axis X at an angle β, as shown in Figure 3. The first and second states of the upper ring 8 define, respectively, a minimum angle and a so-called deployment angle of each of the rods 7. For example, the minimum angle is equal to zero and corresponds to a position of the rods 7 parallel to the longitudinal axis X, as shown in Figure 4.

[0040] In addition, each of the holding elements 4 comprises a locking system (not shown). This locking system allows blocking the rods 7 in a particular position associated with a particular angle β. For example, a locking system is a lock or a clip.

[0041] Moreover, in a preferred embodiment, the net 2 is arranged along the rods 7 according to the longitudinal axis X and about the upper ring 8. The net 2 is made of a polymer material. This type of material allows obtaining a flexible and light net 2.

[0042] Furthermore, the mesh of the net 2 is adapted to the viscosity of the fluid to be damped, in particular liquid hydrogen, present in the reservoir 6 in which the device 1 is arranged. The mesh of the net 2 is defined by at least one parameter representative of the porosity of the net 2. For example, the porosity parameter of the net 2 is comprised between 0.3 and 0.5.

[0043] In the context of the present invention, the device 1 may be brought from a folded position P2, shown in Figures 4 and 6, to an unfolded position P1, shown by Figure 3. The folded position P2 of the device 1 is associated with a configuration of the framework 3 such that the upper ring 8 is in the first state and the angle β between each of the rods 7 and the longitudinal axis X is equal to the minimum angle (preferably zero). The rods 7 are substantially parallel to the longitudinal axis X.

[0044] The unfolded position P1 of the device 1 is associated with another configuration of the framework 3. In this other configuration, the upper ring 8 is in the second state. The angle β between each of the rods 7 and the longitudinal axis X corresponds to the deployment angle. The value of this deployment angle depends on the porosity parameter of the mesh of the net 2 and the viscosity of the fluid.

[0045] The installation and operation mode of the fluid damping device 1, as described hereinabove, is set out hereinafter in a particular embodiment for a preferred application in a reservoir of a spacecraft.

[0046] Before the flight of a spacecraft, the device 1 is fastened in the reservoir 6. To do so, the framework 3 and the net 2 are in a folded configuration, as shown by Figure 4. The folded configuration of the framework 3 and of the net 2 corresponds to rods 7 substantially parallel to each other and to the longitudinal axis X and to an upper ring 8 in the first state.

[0047] Afterwards, as shown in Figure 5, the holding elements 4 are fastened on the part 5. This part 5, which is removable, may be the reservoir access door 6 which is arranged in the lower portion of the reservoir 6. The holding elements 4 are arranged in a circle, as shown in Figure 5.

[0048] The rods 7, which form the framework 3 with the upper ring 8 and the lower ring 10, are arranged in the holding elements 4. As shown in Figure 6, the device 1, which is in its folded position P2, is fastened on the reservoir access door 6.

[0049] The device 1 is inserted into reservoir 6 through an orifice arranged in the lower portion of the reservoir 6. This orifice corresponds to the location of the access door. For example, the diameter of the orifice may be sixty-five centimetres. When this access door is fastened to the reservoir 6, the device 1 is brought from the folded position P2 to an unfolded position P1. In this unfolded position P1, the upper ring 8 is in the second state. The upper ring 8 is a spring, which exerts a return force in a direction opposite to the radial direction of the arrows E. The device 1 is then held in the unfolded position P1 in the reservoir 6, by locking the rods 7 by the locking systems of the holding elements 4.

[0050] The device 1 is unfolded before filling the reservoir 6 with the fluid and the angle of deployment is selected according to the viscosity of the fluid and the porosity parameter of the mesh of the net 2, so as to limit the rocking movements of the fluid. When the device 1 is unfolded and locked, the reservoir 6 is filled with fluid.

[0051] A preferred application of the device 1 is the damping of the rocking movements of the liquid hydrogen present in the reservoir 6 of a spacecraft.

[0052] The actual trajectory of the spacecraft, in particular a launcher, is regularly adjusted during its flight. These adjustments are made by activating the rocket engines of the successive stages. The ergol propellants of the upper stage such as liquid oxygen and liquid hydrogen then move in their respective reservoirs with each control of the attitude of the previous stages. These adjustments take place when the launcher has left the Terrestrial atmosphere and is in a low-gravity or microgravity medium.

[0053] Without damping these rocking movements, the ergol propellants, in particular liquid hydrogen, risk vaporising in contact with hot areas of their reservoir 6, which accordingly reduces the amount of ergol propellants that can be used by the spacecraft during his flight.

[0054] During the flight, the liquid hydrogen level decreases. The free surface between the gas and the liquid hydrogen comes into contact with the net 2. The porosity parameter of the mesh of the net 2 is associated with the Carpenter-Keulegan number. This porosity parameter characterises the effects of the viscosity of the liquid hydrogen and the degree of porosity of the mesh in particular with respect to the amplitude of the load, for example the rocking movements. The value of the porosity parameter is substantially equal to 0.4 so as to maximise a damping ratio when the Carpenter-Keulegan number is equal to 1.

[0055] The rocking movements of the liquid hydrogen are partially or totally reduced by the device 1, the effectiveness of which depends on the angle of deployment and the porosity parameter of the mesh of the net. For example, rocking movements are reduced if the porosity parameter is equal to 0.4 for a deployment angle of 60 degrees.

[0056] In addition, the dimensions of the device 1 are selected so that it is effective according to the maximum of liquid hydrogen in the reservoir 6 when the adjustments of the trajectory under microgravity or low gravity are made. For example, once unfolded, the device 1 measures five metres in diameter and one hundred and fifty centimetres in height according to the longitudinal axis X.

[0057] The fluid damping device 1, as described hereinabove, has the following advantages:

-it is adaptable to various fluids and/or various types of spacecraft reservoirs, in order to reduce the rocking movements and its consequences;

-it is light, which allows increasing the overall performances of the launcher;

-it is adaptable to various flight phases of the spacecraft; and

-it may also allow disrupting vortices and/or retaining bubbles that might be created in the fluid during rocking movements.

[0058] Moreover, the capillarity effects of the net, in microgravity, enable the device to drain the liquid ergol propellant(s) to the bottom of the reservoir.

Patentkrav

1. Indretning til dæmpning af et fluid, der er beregnet til en tank (6), især af et rumfartøj, omfattende en ramme (3), der er forsynet med mindst én ring (8) og en flerhed af stænger (7), hvor enhver af stængerne (7) er fastgjort med en første ende (9A) omkring ringen (8), hvilken indretning (1) omfatter et net (2), der er anbragt på flerheden af stænger (7) og omkring ringen (8), hvor nettet (2) omfatter et netværk, der er tilpasset viskositeten af det fluid, der skal dæmpes, for at dæmpe fluidets bevægelser, hvilken indretning (1) yderligere omfatter en flerhed af holdeelementer (4), hvor enhver af stængerne (7) er anbragt i et holdeelement (4) med en anden ende (9B) over for den første ende (9A), **kendetegnet ved, at**
indretningen er konfigureret til at kunne bringes fra en sammenfoldet position (P2) til en udfoldet position (P1), hvor den sammenfoldede position (P2) svarer til en position af indretningen (1), hvor stængerne (7) er anbragt i det væsentlige parallelt med hinanden, og enhver af stængerne (7) danner en nulvinkel med en akse kaldet længdeaksen (X)) af indretningen (1), hvor den udfoldede position (P1) svarer til en position af indretningen (1), hvor stængerne (7) ikke er parallelle med hinanden, og enhver af stængerne (7) danner en vinkel kaldet udfoldningsvinklen (β), hvor udfoldningsvinklen (β) er forskellig fra nul med længdeaksen (X).

2. Indretning ifølge krav 1, **kendetegnet ved, at** ethvert af holdeelementerne (4) er beregnet til at blive fastgjort til et stykke (5) og til at holde indretningen (1) i det mindste i den udfoldede position (P2).

3. Indretning ifølge et hvilket som helst af de foregående krav, **kendetegnet ved, at** ethvert af holdeelementerne (4) omfatter et låsesystem, der er i stand til at fastlåse stængerne (7) i en position svarende til en udfoldet position (P1) af indretningen (1).

4. Indretning ifølge et hvilket som helst af de foregående krav, **kendetegnet ved, at**ringen (8) kan udvides i en såkaldt radial stilling og er konfigureret således, at den kan bringes fra en første tilstand, når indretningen (1) er i den sammenfoldede stilling (P2), til en anden tilstand, når indretningen (1) er i den udfoldede position (P1), hvor størrelsen af ringen (8) i den første tilstand er mindre end størrelsen af ringen (8) i den anden tilstand.

5. Indretning ifølge et hvilket som helst af de foregående krav, **kendetegnet ved, at** stængerne (7) er fordelt med regelmæssige vinkelintervaller omkring ringen (8).

6. Tank, især til et rumfartøj, **kendetegnet ved, at** den omfatter en indretning til dæmpning af en fluid (1) ifølge et hvilket som helst af kravene 1 til 5.

7. Tank ifølge krav 6, **kendetegnet ved, at** den omfatter et stykke (5), der er anbragt i en nedre del, hvilket stykke (5) er konfigureret til at fastgøre indretningen (1) på tanken (6), hvilket stykke (5) er aftageligt.

8. Rumfartøj omfattende en tank (6) ifølge et af kravene 6 til 7.

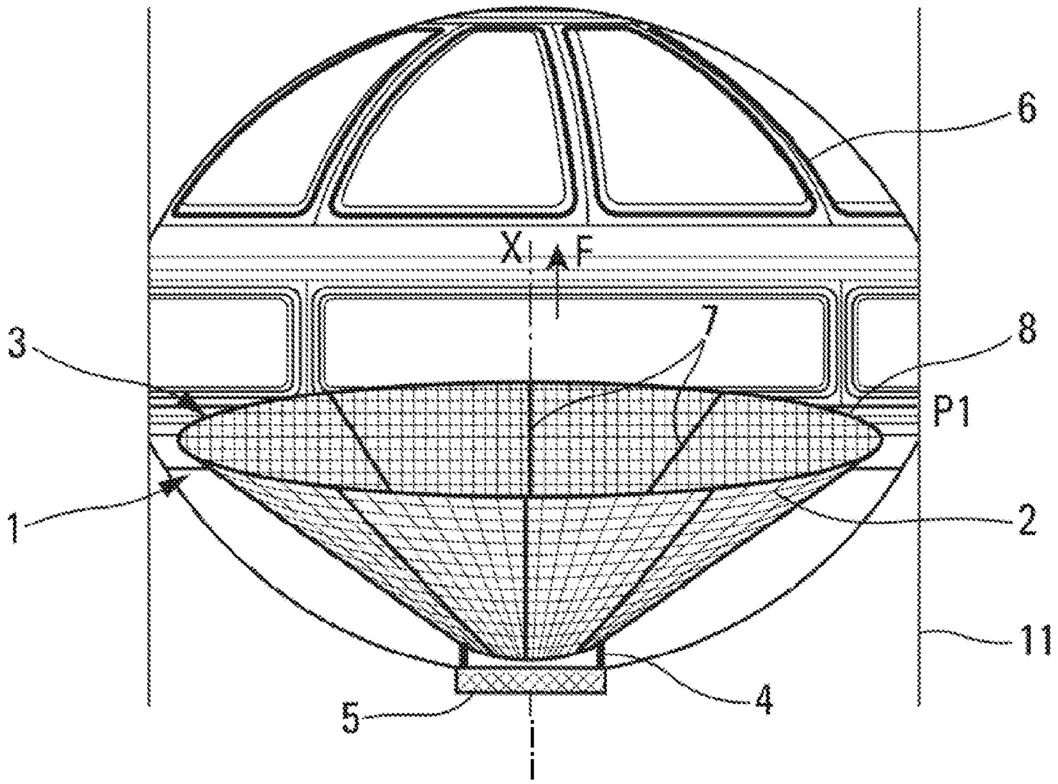

Fig. 1

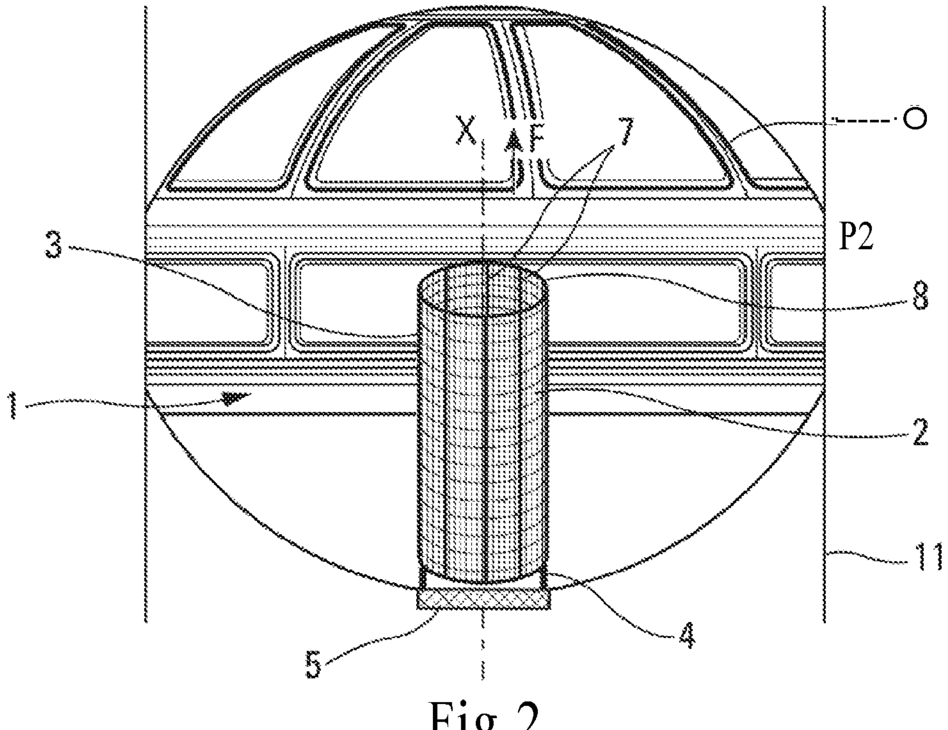

Fig. 2

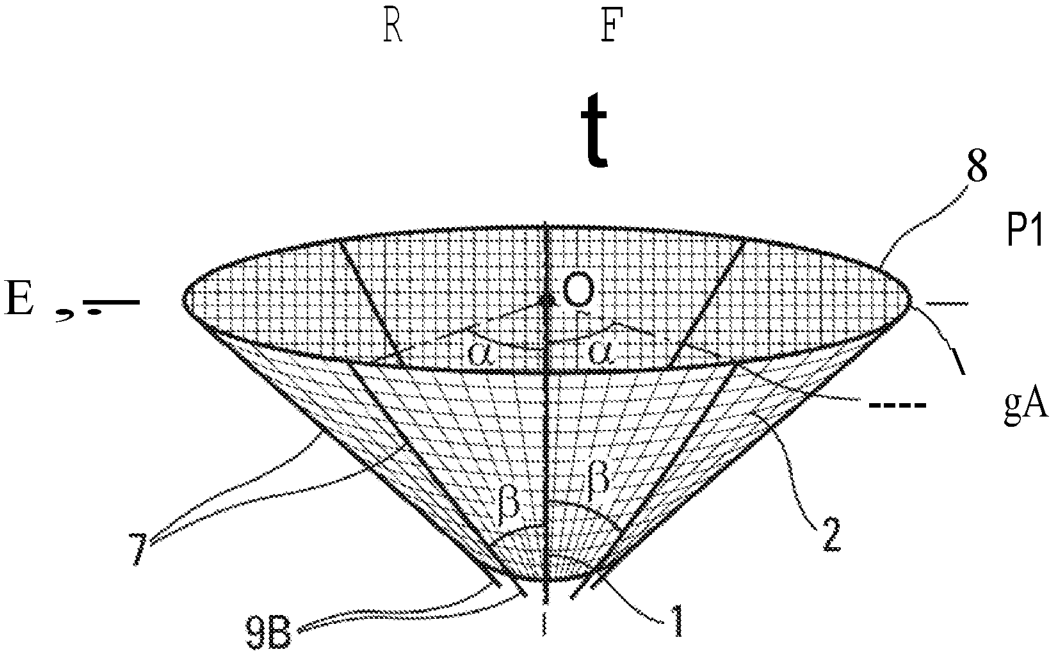

Fig. 3

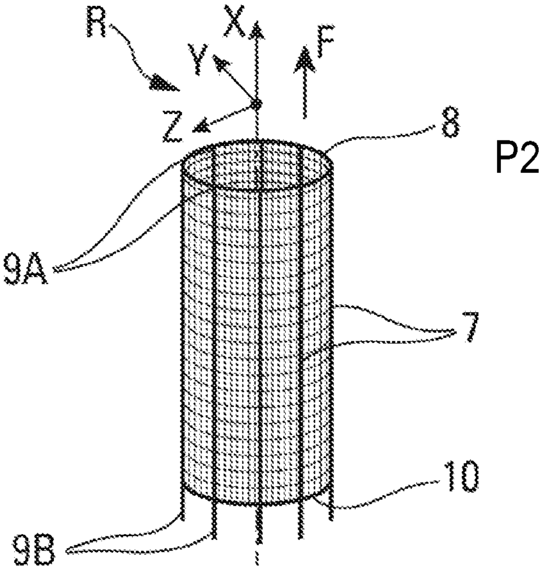

Fig. 4

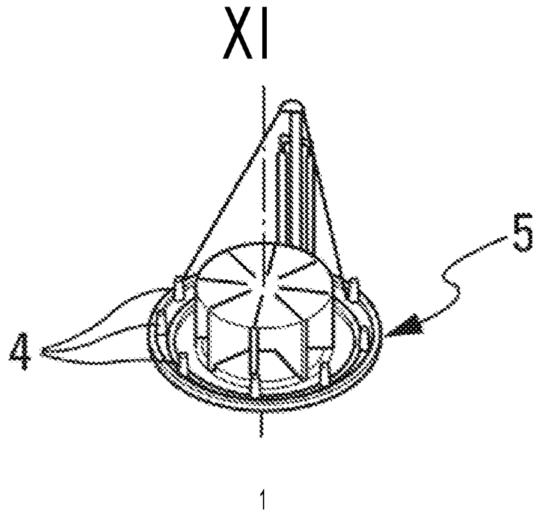

Fig 5

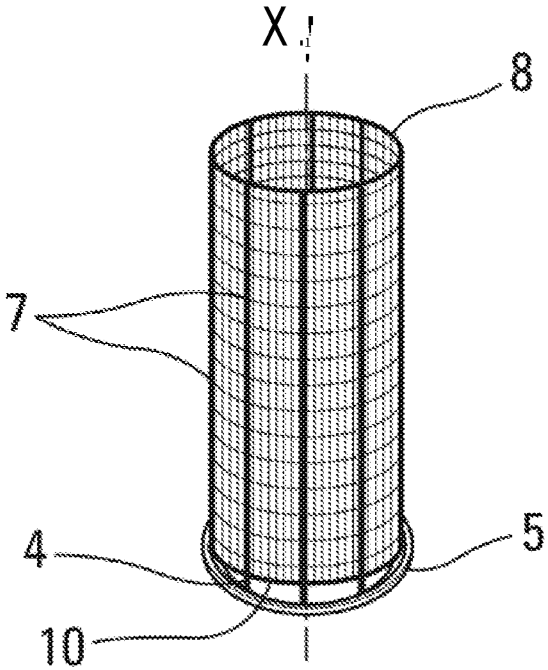

Fig 6