



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
29.08.2012 Bulletin 2012/35

(51) Int Cl.:
F17C 1/16 (2006.01)

(21) Application number: **11159665.6**

(22) Date of filing: **24.03.2011**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(72) Inventors:
• **Verwanger, Peter**
8041 Graz (AT)
• **Verwanger, Irene**
8041 Graz (AT)

(30) Priority: **25.02.2011 EP 11156098**

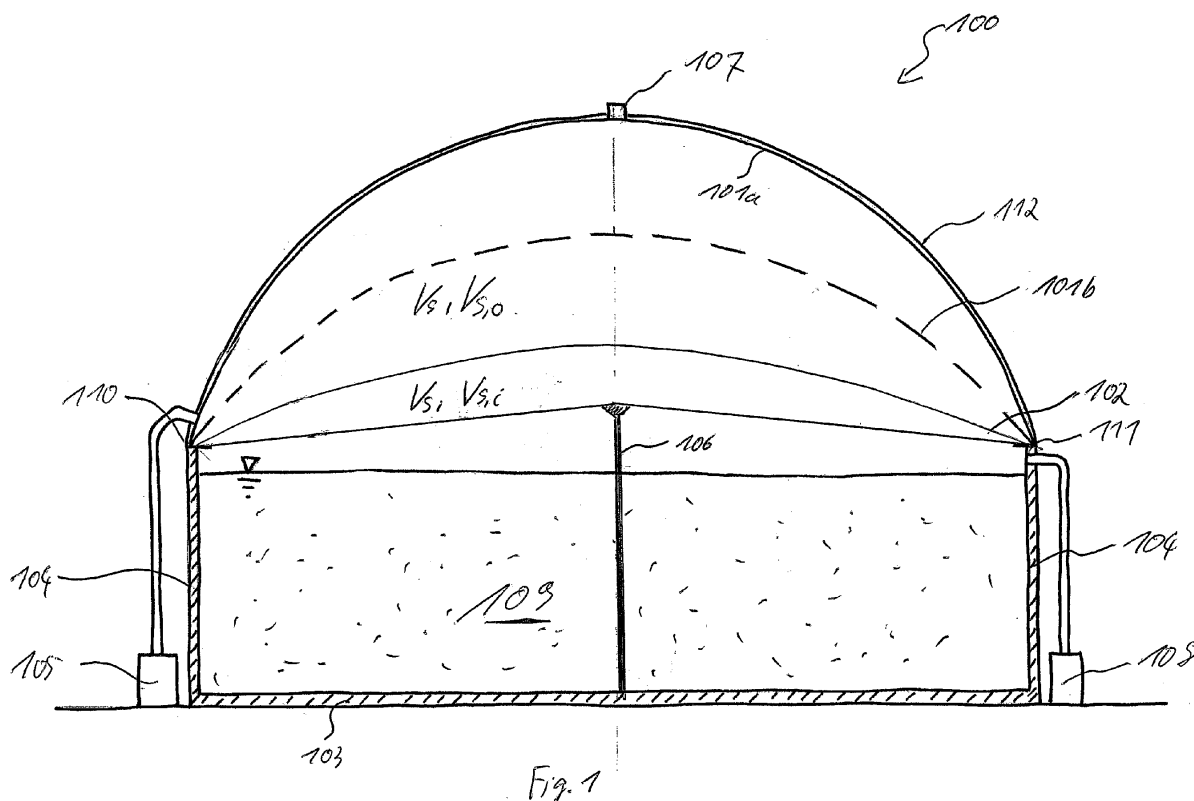
(74) Representative: **Dilg, Andreas et al**
Dilg, Haeusler, Schindelmann
Patentanwalts-gesellschaft mbH
Leonrodstrasse 58
80636 München (DE)

(71) Applicant: **Verwanger, Peter**
8041 Graz (AT)

(54) **Double membrane gas storage with an interior and an exterior membrane**

(57) The present invention relates to covering for a gas storage (100). The covering comprises an interior membrane (102) which is mountable to the gas storage (100) for at least partially enveloping an inner volume ($V_{s,i}$) of the storage (100) for storing industrial gas. Further, the covering comprises an exterior membrane (101)

which is mountable to the gas storage (100), wherein the exterior membrane (101) covers the interior membrane (102) in such a way that an outer volume ($V_{s,o}$) for storing support gas is generated between the exterior membrane (101) and the interior membrane (102). The exterior membrane (101) comprises a material with an ultimate elongation of more than 100%.



Description

Field of the invention

[0001] The present invention relates to a covering for a gas storage and a gas storage to which the covering is mounted. Furthermore, the present invention relates to a method of manufacturing a gas storage.

Background of the invention

[0002] A gas storage, in particular a gas storage for biogas, such as a fermenter of a bio gas plant, comprises a ground plate to which sidewalls of the gas storage are mounted. The open side which is located opposed to the ground plate may be covered by an interior membrane and an exterior membrane. Between the interior and the exterior membrane an outer volume is generated into which a support gas by a blower is blown in for supporting the exterior membrane. This design of the gas storage is called double membrane gas storage.

[0003] The interior membrane and the exterior membrane may be mounted e.g. by a clamping connection to upper edges of the side walls. Between the interior and the exterior membrane the support gas is blown in, such that the outer volume is filled with support gas (e.g. air). The exterior membrane absorbs the loads generated by environmental forces, such as wind loads, snow loads or rain loads. The interior membrane which is located below the exterior membrane divides the storage volume in an outer volume (filled with support gas) and an inner volume (filled with industrial gas). Depending on the filling level of the inner volume, the interior membrane floats in a different height. If the gas storage is filled with industrial gas, the interior membrane is lifted and squeezes the support gas out of the outer volume. The support gas is drained off from the outer volume through a gas control valve or is blown in by a blower. For example, if industrial gas is drained off from the inner volume and thus the interior membrane sinks in the direction to the ground, the blower blows support gas into the outer volume again.

[0004] Double membrane gas storages comprise supporting structures inside the inner volume. A structure comprises e.g. a central pillar with a mesh of belts which are connected between edges of the sidewalls and the central pillar. The belts prevent a sinking of the interior membrane to the ground or i.e. the biomass stored in the fermenter.

[0005] Fig. 5 shows a conventional double membrane gas storage. The gas storage is covered by the exterior membrane 501 and the interior membrane 502 which partially envelopes the inner volume 503. The outer volume 504 is generated between the exterior membrane 501 and the interior membrane 502. A blower 505 is adapted for blowing support gas in the outer volume 504 for preserving a predefined higher pressure in comparison to the environmental pressure of the gas storage. By the pressure in the outer volume 504, the exterior mem-

brane 501 is strained and thus stabilized. The exterior membrane 501 may thus withstand loads from wind or snow. The gas pressure of the support gas affects the interior membrane 502 as well. The interior membrane 502 is flabby and folded. Depending on the filling level of industrial gas in the inner volume 503, the interior membrane 502 floats in a different height. The pressure in the inner volume 503 corresponds to the support gas pressure in the outer volume 504. The pressure in the inner volume 503 is slightly higher than the pressure in the outer volume 504, due to the weight of the interior membrane 502 which affects the inner volume 503. The pressure in the outer volume 504 and thereby the pressure in the inner volume 503 is controllable by a control valve 508 or by the blower 505. The lowest position of the interior membrane is limited by an interior supporting structure 507. The supporting structure 507 prevents the interior membrane 502 from touching the ground, the biomass inside the gas storage or rotating stirring devices 509 which could damage the interior membrane 502. The filling level is measured by a level indicator 506, which measures the position of a point or section on the interior membrane 502. The exterior membrane 501 is manufactured in a predefined shape, such as a half ball shape. If the pressure in the outer volume 504 falls, the material of the exterior membrane with conventional materials, such as PVC coated polyester fabrics, cannot shrink and adapt the falling pressure such that the exterior membrane 501 forms foldings and becomes instable.

[0006] Fig. 6 shows a conventional double membrane gas storage, wherein the exterior membrane 601 and the interior membrane 602 are mounted to the ground 10. The storage volume 603 is enveloped by the ground 10 and the interior membrane 602. Furthermore, a blower 605, a level indicator 606 and a control valve 608 is shown which are similar to the respective features of Fig. 5

[0007] Fig. 7 shows a conventional gas storage, wherein the blower 705 fails or wherein the exterior membrane 701 has a leakage 711. The support gas pressure in the outer volume collapses. Hence, the exterior membrane is flabby and folded and is thus not longer stable. The exterior membrane 701 cannot withstand the loads from wind and snow. The operation of the double membrane gas storage has to be stopped for preventing an aggravation of the damage.

[0008] Fig. 8 shows a conventional gas storage, wherein the result of a leakage 812 in the interior membrane 802 is shown. Industrial gas streams through the leakage 812 out of the inner volume 803 in the outer volume 804. This may cause an explosive gas mixture in the complete outer volume 804. The mixed explosive gas will be drained off to the environment by the control valve 808 which cause undesired gas emissions.

[0009] Fig. 9 shows a position of a conventional interior membrane 902 which is not tightened. The level indicator 906 measures a full level of gas due to a measurement of a peak point of a folding, although sufficient storage volume would still be available.

[0010] Fig. 10 shows a position of the interior membrane 902 in a conventional gas storage, with which the level indicator 906 measures an empty level of gas due to a measurement point at a minimum height of the folded interior membrane, although the gas storage is almost maximally filled. Fig. 9 and Fig. 10 describe the inadequate level measurement and the limited usability of a conventional gas storage due to a folded, non-tightened conventional interior membrane 902.

[0011] In the following above indicated default risks of the conventional gas storages will be summarized:

For the stability of the exterior membrane it is necessary that the support gas pressure in the outer volume does not fall below a predetermined minimum support gas pressure. If a breakdown of the blower occurs (motor defect, blackout ...etc.) the support gas pressure is reduced. The exterior membrane loses its tension and is flabby and is not longer stable against environmental loads, such as loads caused by wind and snow. The support gas will stream outside the outer volume step by step and the exterior membrane will sink to the ground. Hence, the gas storage has to be taken out of operation.

[0012] If a larger leakage in the exterior membrane occurs, e.g. by a rip of a joining seam, support gas streams out of the outer volume. The support gas pressure breaks down and the gas storage has to be taken out of operation.

[0013] If a leakage in the interior membrane occurs, industrial gas streams out of the inner volume in the outer volume. Beside the polluting emission of the industrial gas, a large amount of explosive gas mixtures may be generated in the outer volume. Hence, the explosion risk increases. Hence, the gas storage has to be taken out of operation.

[0014] The weld seam strength of the conventionally used PVC coated polyester fabrics is reduced under high temperatures. The temperatures of the conventional exterior membranes are very high under certain circumstances (solar irradiation, dark colors of exterior membrane, dirt particles on the exterior membrane). This high temperature may cause a defect in the weld seams due to the weakness of the PVC coating.

[0015] On the other side, under low temperatures, the PVC coated polyester fabrics are very brittle. For this reason, installation of the exterior membrane under low temperatures is not possible. Furthermore, during changing operating conditions of the gas storage, the membranes may form foldings. This would lead to a buckling of the membranes and thus to a defect under low temperatures. When buckling the PVC coated polyester fabrics the coating breaks and the fibres may be no longer covered by the coating.

[0016] Moreover, exterior membranes made of PVC coated polyester fabrics, which are very stiff and hardly

stretchable or contractible, have to be tailored in the final shape which have to be formed by the membranes in the operating state of the gas storage (such as a half ball shape). The interior membrane has only in the maximum filled inner volume or empty inner volume the defined end position. The position of the interior membrane is not locatable in a partially filled inner volume. The measurement of the position and shape of the interior membrane and thus of the filling level is thus not very precise. Mostly, only a part of the inner volume may be used for storing industrial gas due to the imprecise filling level measurement.

[0017] Moreover, even if the inner volume is partially filled with industrial gas, parts of the interior volume may be located at a lower position and other parts may be located at a higher position inside the gas storage. The interior membrane may be damaged by the stirring biomass or the stirring device inside the inner volume. PVC coated polyester fabrics may be damaged and a durable contact with the biomass may embrittle the coating. Hence, a supporting structure is installed in the inner volume, wherein the supporting structure limits the lowest position of the interior membrane. The supporting structure may cause high production and installation costs.

[0018] Summarizing, the disadvantages with the conventional storages may be a breakdown, if the blower fails, or a breakdown, if a leakage in the interior or exterior membrane occurs. Moreover, the filling level is not measurable precisely and the maximal storage volume is not usable due to the imprecise filling level measurement. Moreover, the tailoring of the membranes in a curved (half ball) shape causes high production costs. Moreover, the PVC coated polyester fabrics comprise a poor temperature resistance.

Object and summary of the invention

[0019] It may be an object to provide a robust covering for a gas storage with low manufacturing costs and a low system complexity.

[0020] This object is solved by a covering for a gas storage, a gas storage and by a method of manufacturing a storage for a gaseous medium according to the independent claims.

[0021] According to a first aspect of the present invention, a covering for a gas storage is presented. The covering comprises an interior membrane which is mountable to the gas storage for at least partially enveloping an inner volume of the gas storage for storing industrial gas and an exterior membrane which is mountable to the gas storage, wherein the exterior membrane covers the interior membrane in such a way that an outer volume for storing support gas is generated between the exterior membrane and the interior membrane. The exterior membrane comprises a material with an ultimate elongation of more than 100% (e.g. measured under a temperature of 23° degree Celsius).

[0022] According to a further aspect of the present in-

vention, a gas storage for an industrial gas is presented. The gas storage comprises the above described covering. The interior membrane is mounted to the gas storage for at least partially enveloping the inner volume. The exterior membrane is mounted to the gas storage wherein the exterior membrane covers the interior membrane in such a way that an outer volume for storing support gas is generated between the exterior membrane and the interior membrane.

[0023] According to a further aspect of the present invention, a method of manufacturing a storage for a gaseous medium is presented. The method comprises mounting an interior membrane to the gas storage for at least partially enveloping an inner volume of the gas storage for storing industrial gas and mounting an exterior membrane to the gas storage, wherein the exterior membrane covers the interior membrane in such a way that an outer volume for storing support gas is generated between the exterior membrane and the interior membrane. The exterior membrane comprises a material with an ultimate elongation of more than 100% (e.g. measured under a temperature of 23° degree Celsius).

[0024] The storage for a gaseous medium may comprise any desired tubular shape, for example with a circular, oval, rectangular or polygonal ground area. An open top side of the storage is covered by the above-described interior and exterior membrane, so that within the interior of the storage the storage volume with the inner and outer volume is provided. The storage may alternatively be formed by a ground plate to which the exterior membrane is mounted.

[0025] The gaseous medium comprises components of industrial gas, such as natural gas or biogas, and components of support gas, such as air or inert gas. Moreover, the storage device may be a biogas storage, so that additionally to the gaseous medium biomass may be stored within the storage. In this case, the storage volume for the gaseous medium is the volume that is enveloped by the biomass, the membrane and in some embodiments the sidewall of the storage.

[0026] The ultimate elongation is a material property and is defined by:

$$A = \frac{\Delta L}{L_0} \cdot 100\%$$

wherein A is the ultimate elongation,
wherein ΔL is the length difference between the start length of a probe and the length of the probe at which the probe fails;
wherein L_0 is the length at the beginning of the test or under a force-free unexpanded condition.

[0027] An ultimate elongation of more than 100% defines a material, which is adapted to withstand an elon-

gation of its length of more than the double length ($A=100\%$) of the start length.

[0028] In contrary to previous approaches, the exterior membrane and/or the interior membrane described by the present invention comprises a material with an ultimate elongation of more than 100% and is expandable and stretchable. Moreover, the interior membrane may as well comprise a material with an ultimate elongation of more than 100%. The material may be elastic or ductile.

[0029] Due to the stretchable characteristic of the material, the exterior membrane and/or the interior membrane may be manufactured in a plane panel shape or plane plate shape. The exterior membrane and/or the interior membrane may in particular be made of a fibre-free material, i.e. the membrane is not made of a material with inductile fibres. Moreover, the exterior membrane and/or the interior is made of a foil-like material. Moreover, the material of the exterior membrane and/or the interior membrane may be an elastomer and/or a thermoplastic elastomer.

[0030] If a blower blows support gas into the outer volume, the exterior membrane is stretched from its plane shape until the exterior membrane forms a balloon like shape. The membrane is stretched until the tension of the membrane and the pressure in the inner volume form an equilibration. The manufacturing of the exterior membrane in the shape of a plane panel is easy and cost saving. If a larger curvature is desired the exterior membrane may be manufactured in a cone like shape and a cylindrical shape. The stretched final curved shape in the nominal operating condition may be reached after the exterior membrane is stretched by the support gas pressure.

[0031] If the blower for the support gas fails or a leakage in the exterior membrane occurs, support gas streams out of the outer volume. The stretched exterior membrane tightens until the exterior membrane lies onto the interior membrane. The exterior membrane still comprises a minimal tension due to its stretching characteristic. Hence, a gas pressure in the inner volume below the membranes may be still kept stable and thus a stability of the membranes may be ensured. The storage function is still provided, because the inner volume and the position of the membranes are still amendable.

[0032] A use of a stretchable interior membrane and a stretchable exterior membrane leads in combination to the technical effect that the gas storage may be further operated even if a leakage in the interior membrane occurs. If a leakage in the interior membrane occurs, the blower may be switched off and the support gas pressure is reduced so that the exterior membrane sinks until the exterior membrane lies onto the interior membrane. Hence, the leakage is sealed by the exterior membrane. The gas storage may be further operated with a reduced gas pressure. A stiff and only little stretchable interior membrane forms foldings, such that the exterior membrane can only hardly generate a sealing contact with

the interior membrane around the region of the leakage.

[0033] By the defined curve shape of the stretched, folding-free interior membrane the filling level of the inner volume may be measured more exactly. One height position of a predetermined point onto the interior membrane may be measured. The height position of the predetermined point may be indicative for the shape of the interior membrane and thus for the filling level.

[0034] By the present invention, the exterior membrane is formed for being expandable (stretchable) and shrinkable according to the pressure of the support gas in the outer volume. Even if the gas pressure in the outer volume decreases, the exterior membrane shrinks and reduces its area size, so that the storage volume is reduced. Hence, the pressure in the storage volume and the tension of the membrane is kept in between predetermined pressure ranges due to the reduced area size of the exterior membrane and a sufficient tension of the exterior membrane is still provided that prevents the exterior membrane from leaving its homogeneous shape. In other words, due to the stretching and expanding properties of the exterior membrane, the area size of the exterior membrane is adaptable and amendable to the respective pressure of a gaseous medium in the storage volume. Hence, if a tension of the exterior membrane is still kept up, so that e.g. fluttering of the exterior membrane under influence of wind may be prevented.

[0035] According to a further exemplary embodiment, the exterior membrane is formed in such a way that the exterior membrane has a stretch ratio between an expanded condition of the exterior membrane in a regular operating condition and a force-free unexpanded condition of the exterior membrane of more than 1, 1.

[0036] The force-free unexpanded condition of the exterior membrane defines the condition of the exterior membrane, at which i.e. no tractive forces or pressure forces caused due to a pressure difference between the pressure of the storage volume and an ambient pressure act. Under the term force-free unexpanded condition a condition is described, where generally only e.g. the weight force of the respective membrane loads the respective membrane.

[0037] The expanded condition of the exterior membrane defines the length, the diameter or preferably the area size of the exterior membrane in which expanded condition the exterior membrane reaches an expansion under regular operating conditions. In particular, the expanded condition under regular operating conditions describes the elongation when the gas storage runs under regular operating conditions. The regular operating condition particularly describes a pressure range of the gas in the storage volume (inner volume, outer volume) between which pressure range the gas storage and the membrane is designed for operation. The regular operating conditions for a gas storage are defined e.g. in the specifications defined by a manufacturer of a respective gas storage.

[0038] If the exterior membrane is stretched with the

above described stretch ratio of more than 10% (1,1) in the operating condition, the exterior membrane is in other words stretched in comparison to its force-free unexpanded state. Hence, if the gas pressure in the storage volume is reduced due to a leakage in the exterior membrane, the pressure in the storage volume falls out of the pressure range defining the regular operating condition.

[0039] Because the exterior membrane is stretched in the regular operating condition, the exterior membrane contracts due to a pressure reduction caused by leakage of the exterior membrane. The contraction ability of the exterior membrane is necessary for maintaining a stability and an operation of the gas storage even if the blower for the support gas fails and/or the exterior membrane pressure leaks. By the contraction of the exterior membrane, the exterior membrane adapts its shape to the shape of the interior membrane until the exterior membrane has a similar size and shape as the interior membrane, so that the exterior membrane contacts the interior membrane. By this contact, the exterior membrane seals the leakage of the interior membrane. Hence, an operation of the gas storage is still possible at least with a reduced pressure, because the exterior membrane seals the leak of the interior membrane.

[0040] The higher the stretch ratio of the exterior membrane in the regular operating condition, the larger the contraction capability of the exterior membrane, which leads to a better adaption of the exterior membrane to shape of the interior membrane for sealing a leak of the interior membrane. The stretch ratio of the exterior membrane is larger than 1, 1 for generating a proper contraction ability between a regular operating condition and a lower, non-regular operating condition.

[0041] The predetermined pressure value for defining a lower limit of the pressure range of the regular operating condition may be defined by a pressure difference between the pressure in the storage volume and the environment pressure (e.g. standard environment pressure of 1013 hPa according to International Standard Atmosphere (ISA)). The pressure difference and thus the lower limit may be larger than approximately 1 mbar or more for the pressure range in the operating conditions.

[0042] The stretch ratio (extension ratio) is a measure of the extensional or normal strain of a differential line element or of a differential area of an elemental area. The stretch ratio may be defined as described above and by the following formula:

$$\lambda = \frac{a}{A}$$

[0043] wherein

λ is the stretch ratio;

a is the area of the exterior membrane in the expand-

ed condition under regular operating condition; and
 A = area of the exterior membrane in a force-free unexpanded condition.

[0044] The area size of the exterior or interior membrane may be illustrated and calculated by a surface integral that is taken over the surface of the exterior or interior membrane. Hence, curved surfaces of the exterior membrane that describes e.g. a shape of half hollow ball may be defined and calculated as well, so that the stretch ratio may be defined. Alternatively, the stretch ratio may as well be expressed by a ratio between a length of the exterior membrane along its surface between the expanded condition under regular operating condition and the force-free unexpanded condition. The length of a membrane may be defined by a length of a line between two mounting points at which the membrane is fixed to e.g. a sidewall or a ground plate of the storage. Hence, the length of the line between the two mounting points, which line runs along the surface of the exterior membrane, may be calculated by a line integral. For example, when taking a line between the two mounting points, the connection line along the surface of the exterior membrane between the mounting points may form for example a curved shape, such as a parable or a half circle, for example. Hence, the ratio between the lengths along the surface of the exterior membrane in the expanded condition under regular operating condition into the length of a line on the surface of the exterior membrane in the force-free unexpanded condition may define the stretch ratio as well.

[0045] In particular, the stretch ratio for the exterior and/or interior membrane according to the present invention is approximately more than 1, 1. In particular, the stretch ratio of the exterior membrane for the pressure in the operating condition is between approximately 1, 1 and approximately 4, and more particularly between approximately 2 and approximately 3. In particular, the above described values for the stretch ratio of the exterior and/or interior membrane may be valid at ambient temperatures of approximately -40°C to approximately 100°C, and more particularly between approximately -20°C to approximately 70°C.

[0046] The exterior membrane and/or the interior membrane may in particular be made of a fibre-free material, i.e. the membrane is not made of a material with inductile fibres. Moreover, the exterior and/or the interior membrane is made of a foil-like material. Moreover, the material of the exterior membrane and/or the interior may be an elastomer and/or a thermoplastic elastomer, so that a shape and an area size of the exterior membrane and/or the interior membrane is adaptable to a pressure of the gaseous medium in the outer volume and/or inner volume, respectively.

[0047] In gas storages, the exterior and/or the interior membrane may cover an area surface between 150 m² (square meter) and 1300 m² (square meter). Interior and/or exterior membranes according to the present in-

vention comprise a width or a diameter of the gas storage of approximately 15 m to approximately 45 m (meter) or more.

[0048] According to a further exemplary embodiment, the material of the exterior membrane and/or the interior membrane is an elastomer or a thermoplastic elastomer, in particular a synthetic rubber.

[0049] According to a further exemplary embodiment, the material of the exterior membrane and/or the interior membrane is ethylene propylene diene monomer (EPDM). EPDM is a type of synthetic rubber and an elastomer. An EPDM elastomer is usable in a temperature range of approximately -50°C to approximately 110°C without failing.

[0050] According to a further exemplary embodiment, the exterior membrane and/or the interior membrane is formed homogeneous. In particular, the exterior membrane may be formed of one piece or a plurality of sub-pieces, wherein in the force-free unexpanded condition, the exterior membrane may extend along a plane. In that case, the dome-like shape of the exterior membrane is formed by a stretching of the exterior membrane if the pressure in the outer volume increases. In previous approaches, stiff and non-stretchable membranes are used, so that the membranes have to be formed in the final shape e.g. in the dome-like shape of the membrane. Hence, the conventional membranes have to be tailored and provided with a plurality of seams, which leads to higher manufacturing costs and manufacturing time. By the stretchable exterior membrane according to the present invention, in the original and unstretched state, the stretchable membrane may be plane, i.e. with a flat and substantial two dimensional shape. The curvature in an operating state of the gas storage is achieved by stretching the stretchable membrane due to a respective gas pressure in the storage volume. Hence, tailoring of the exterior or interior membrane is easy.

[0051] According to a further exemplary embodiment of the present invention, the covering further comprises an outer support structure. The outer support structure is mounted over the exterior membrane, so that the exterior membrane is alignable at the outer support structure when the exterior membrane forms a predetermined shape and/or expands due to the gas pressure in the storage volume exceeding a predetermined pressure value. If the exterior membrane is pressed and aligned against the outer support structure, a load transmission between the exterior membrane and the outer support structure is generated, so that the outer support structure is able to restrain the exterior membrane.

[0052] In particular, according to a further exemplary embodiment, the outer support structure comprises elongated restraining elements, particularly cables, belts or ropes or a (fine meshed) mesh. In particular, according to a further exemplary embodiment, the mesh has mesh openings, wherein each mesh opening is formed with a size such that sub-portions of the exterior membrane are prevented from expanding through the mesh opening

when the gas pressure in the storage volume exceeds a predetermined pressure value, so that the gas pressure is within a pressure range of the operating conditions of the gas storage.

[0053] According to a further exemplary embodiment of the gas storage, the storage further comprises a ground plate and a sidewall mounted to the ground plate. The exterior membrane, the interior membrane and/or the supporting structure is/are mounted to the sidewall so that the storage volume is enveloped by the sidewall, the exterior membrane, the further interior membrane and the ground plate. In a further exemplary embodiment, the exterior membrane and/or further interior membrane is mounted to an edge of a hole in a ground (e.g. a syncline), so that the storage volume is formed by the exterior membrane and a surface of the hole in the ground.

[0054] The interior membrane is mounted for example to the ground plate or the sidewall of the storage and envelops an inner volume of the storage volume, where the industrial gas component is stored. In particular, the interior membrane may be made of an elastomeric material, so that the shape and the size of the interior membrane is adaptable to a pressure of the gaseous medium and the storage volume, e.g. to a pressure difference between the industrial gas in the inner volume and a pressure of the support gas component in the outer volume. The interior membrane may have the same properties and the same material as the exterior membrane as described above. For example, the material of the interior membrane is ethylene propylene diene monomer (EPDM).

[0055] By providing a stretchable interior membrane, the shape and the position of the interior membrane may be kept homogeneous, i.e. without foldings and pocket-like curvatures in the force-free unexpanded condition, even if the pressure in the inner volume decreases. In particular, if the pressure in the inner volume decreases, the interior membrane contracts without becoming flabby, folded and inhomogeneous and without leaving its defined shape. In other words, even if the pressure in the inner volume decreases, the interior membrane does not form foldings and pockets for example, but keeps a homogeneous surface, such as a half ball-shaped surface.

[0056] This has the additional effect, that a measurement by a level indicator is improved. In particular, in gas storages the inner volume may be determined by measuring the distance between the exterior membrane and the interior membrane. These measurements may be distorted if the interior membrane forms foldings, for example.

[0057] According to a further exemplary embodiment, the storage further comprises a support gas supply unit which is installed in such a way that the support gas is supplied into the outer volume for adjusting a predetermined support gas pressure in the outer volume.

[0058] According to a further exemplary embodiment, the storage further comprises an inner support structure which is installed to the storage in such a way that the

interior membrane is aligned at the inner support structure if the interior membrane contracts due to a gas pressure in the inner volume falls below a predetermined pressure value.

[0059] According to a further exemplary embodiment, the storage is free of the inner support structure so that the interior membrane is freely movable even when the interior membrane contracts due to a gas pressure in the inner volume falling below the predetermined pressure value.

[0060] Hence, if the pressure values in the volume of the storage changes it happens that the membrane collapses and forms foldings. This is reasoned because the conventional membranes have not the capability of reducing its area size, so that the storage volume is not reduced by a shrinking of the conventional membranes even if the inner pressure in the storage volume sinks.

[0061] By the present invention, the exterior membrane has a material with an ultimate elongation of more than 100% and is formed for being expandable and shrinkable according to the pressure of the support gas in the outer volume. If the gas pressure in the outer volume decreases, the exterior membrane shrinks and reduces its area size, so that the outer volume is reduced. Hence, the pressure in the outer volume is kept in between predetermined pressure ranges due to the reduced area size of the exterior membrane. Thereby, a sufficient tension of the exterior membrane is still provided that prevents the exterior membrane from leaving its homogeneous shape. In other words, due to the stretch and expanding properties of the exterior membrane, the area size of the exterior membrane is adaptable and amendable to the respective pressure of a gaseous medium in the storage volume. Hence, if a tension of the exterior membrane is provided, e.g. fluttering of the exterior membrane in the wind may be prevented.

[0062] According to a further exemplary embodiment, the storage further comprises a level indicator for measuring the storage volume. The level indicator may measure the storage volume for example by measuring the position of (i.e. a predetermined point on) the interior membrane and/or the exterior membrane by an ultrasonic measurement or by measuring the differential pressure between the inner pressure in the inner volume and the pressure in the outer volume. By using an ultrasonic level indicator, the ultrasonic level indicator may be mounted to the top of the exterior membrane, so that the distance to the ground, to the biomass in the storage or to the distance to the interior membrane may be measured.

[0063] According to a further aspect of the present invention, the storage for storing a gaseous medium is presented. The storage comprises an interior membrane for at least partially enveloping the inner volume into which industrial gas is storable and a gas supply unit which is connected to the inner volume for supplying support gas to the inner volume, so that the gas pressure in the inner volume is prevented from falling below a predetermined nominal gas pressure and/or a position of the interior

membrane is prevented from falling below a predefined position limit.

[0064] The support gas may be selected from one of the group consisting of inert gases, natural gases, helium gases, halogen gases and air. Moreover, the support gas may be an industrial gas which is of the same condition as the industrial gas regularly stored in the storage.

[0065] If the gas pressure in the storage volume falls below a predetermined nominal gas pressure, the support gas is fed to the storage volume, so that the gas pressure in the storage volume increases above the nominal gas pressure. Hence, the supply unit prevents the membrane from folding and losing its tension. The gaseous medium in the storage volume will be mixed with the support gas supplied by the gas supply unit.

[0066] According to a further exemplary embodiment, the storage comprising the membrane and the gas supply unit is a storage as described above.

[0067] It has to be noted that embodiments of the invention have been described with reference to different subject matters. In particular, some embodiments have been described with reference to apparatus type claims whereas other embodiments have been described with reference to method type claims. However, a person skilled in the art will gather from the above and the following description that, unless other notified, in addition to any combination of features belonging to one type of subject matter also any combination between features relating to different subject matters, in particular between features of the apparatus type claims and features of the method type claims is considered as to be disclosed with this application.

Brief Description of the Drawings

[0068] The aspects defined above and further aspects of the present invention are apparent from the examples of embodiment to be described hereinafter and are explained with reference to the examples of embodiment. The invention will be described in more detail hereinafter with reference to examples of embodiment but to which the invention is not limited.

[0069] Fig. 1 shows a gas storage for a gaseous medium comprising sidewalls to which a covering is mounted, according to an exemplary embodiment of the present invention;

[0070] Fig. 2 shows a gas storage with membranes mounted to a ground plate according to an exemplary embodiment of the present invention;

[0071] Figs. 3 and 4 show a storage comprising elongated restraining elements according to exemplary embodiments of the present invention, and

[0072] Fig. 5 to Fig. 10 show conventional gas storages of the prior art.

Detailed Description

[0073] The illustrations in the drawings are schemati-

cally. It is noted that in different figures, similar or identical elements are provided with the same reference signs.

[0074] Fig. 1 shows a storage 100 for a gaseous medium. The storage 100 comprises a covering with an interior membrane 102 and an exterior membrane 101. The interior membrane 102 is mounted to the gas storage for at least partially enveloping an inner volume $V_{s,i}$ of the storage 100 for storing industrial gas. The exterior membrane 101 is mounted to the gas storage 100, wherein the exterior membrane 101 covers the interior membrane 101 in such a way that an outer volume $V_{s,o}$ for storing support gas is generated between the exterior membrane 101 and the interior membrane 102. The exterior membrane 101 comprises a material with an ultimate elongation of more than 100%.

[0075] The exterior membrane 101 may be made of an elastomeric material, so that the shape and an area size of the exterior membrane 101 are adaptable to a pressure of the gaseous medium in the storage volume V_s . The exterior membrane 101 is formed in such a way that an area of the exterior membrane 101 has a stretch ratio between an expanded condition under regular operating conditions of the exterior membrane 101 and a force-free unexpanded condition of the exterior membrane 101 of more than 1,1.

[0076] Moreover, as shown in Fig. 1, an interior membrane 102 is mounted. The interior membrane 102 is mounted in such a way that the interior membrane 102 divides the storage volume V_s in the inner volume $V_{s,i}$ for storing an industrial gas of the gaseous medium and the outer volume $V_{s,o}$ for storing the support gas. The outer volume $V_{s,o}$ is generated between the exterior membrane 101 and the interior membrane 102.

[0077] The industrial gas may comprise for example a biogas, a natural gas or liquid gas. The support gas may be for example an inert gas, a helium gas or air. The interior membrane 102 may have the same (material) properties as the exterior membrane 101.

[0078] As shown in Fig. 1, the exterior membrane 101 is shown in an expanded condition 101a (shown with the solid line in Fig. 1). With the dotted line shown in Fig. 1, a less expanded condition 101b in comparison to the expanded condition 101a of the exterior membrane 101 is shown. If the gas storage operates in a regular operating condition, the expanded condition 101a and the less expanded condition 101b may be formed by the gas pressure in the storage volume V_s , in particular by the support gas pressure in the outer volume $V_{s,o}$.

[0079] As can be taken from Fig. 1, the exterior membrane 101 has a tension of the surface, so that e.g. foldings may be prevented.

[0080] Moreover, it is possible to measure the length of a line along the surface of the exterior membrane 101 between a first mounting point 110 and a second mounting point 111. By the mounting points 110, 111 the exterior membrane 101 may be fixed to a side wall 104 or a ground plate 103 of the storage 100. Hence, instead of taking the area sizes a , A for calculating the stretch ratio,

it is also possible to take the lengths of the line between the first mounting point 110 and the second mounting point 111. The stretch ratio may then be calculated by the ratio between the length l of the exterior membrane 101 in the expanded condition under regular operating conditions and the length L of the exterior membrane 101 in the force-free unexpanded condition.

[0081] Fig. 1 shows furthermore the storage 100 with the sidewall 104 and the ground plate 103. The storage volume V_s is enveloped by the sidewall 104, the ground plate 103 and the exterior membrane 101.

[0082] Optionally, in order to prevent a contact of the interior membrane 102 with the ground plate 103 or the biomass 109, an inner support structure 106 may be installed into inner volume $V_{s,i}$ of the storage 100. The inner support structure 106 may comprise one or more supporting masts that support the interior membrane 102. Moreover, the inner support structure 106 may comprise a plurality of supporting belts or cables onto which the interior membrane 102 may be aligned if the gas pressure in the inner volume $V_{s,i}$ fall below the nominal gas pressure value.

[0083] Additionally a support gas supply unit 105 may be installed and connected to the storage 100. The support gas supply unit 105 supplies support gas into the outer volume $V_{s,o}$. Hence, a pressure in the outer volume $V_{s,o}$ may be kept generally in between predetermined pressure ranges even when the outer volume $V_{s,o}$ increases due to a contraction of the interior membrane 102 and due to a movement of the interior membrane 102 in the direction to the ground plate 103. Hence, the tension and the size of the exterior membrane 101 may be sustained by keeping the pressure in the outer volume $V_{s,o}$ generally in between predetermined pressure ranges.

[0084] Furthermore, in order to prevent a contact between the interior membrane 102 and the ground plate 103 or the biomass 109, a gas supply unit 108 may be connected to the inner volume $V_{s,i}$, so that the pressure in the inner volume $V_{s,i}$ is held above a nominal gas pressure in the inner volume $V_{s,i}$ in order to prevent a further contraction of the interior membrane 102.

[0085] The support gas may be for instance an inert gas or an industrial gas for preventing a dilution of the stored industrial gas, for example.

[0086] Further referring to Fig.1, a level indicator 107 may be mounted to a top of the exterior membrane 101. The top of the exterior membrane 101 is in general the highest point of the storage 100. The level indicator 107 may measure the inner volume $V_{s,i}$ for example by measuring the position of the interior membrane 102 and/or the exterior membrane 101 by an ultrasonic measurement or by measuring the differential pressure between the inner pressure in the inner volume $V_{s,i}$ and the pressure in the outer volume $V_{s,o}$.

[0087] The storage 100 in Fig. 1 further shows an outer support structure 112. The exterior membrane 101 is expanded by the pressure in the outer volume $V_{s,o}$ until

the exterior membrane 101 aligns at the outer support structure 112. The outer support structure 112 may comprise ropes or belts which e.g. forms a fine-meshed mesh.

[0088] Fig. 2 shows a further exemplary embodiment of the storage 100, wherein the exterior membrane 101 and the interior membrane 102 are mounted directly to the ground plate 103.

[0089] The exterior membrane 100 is shown in an expanded condition 101a and in a lesser expanded condition 101b. Furthermore, below the exterior membrane 101, the interior membrane 102 is mounted. Between the ground plate 103 and the interior membrane 102 the inner volume $V_{s,i}$ of the storage volume V_s is generated. In the inner volume $V_{s,i}$ the industrial gas is stored.

[0090] Moreover, the support gas supply unit 105 is shown which supplies support gas into the outer volume $V_{s,o}$, so that a minimum gas pressure inside the outer volume $V_{s,o}$ will not be under-run. Hence, a minimal tension of the exterior membrane 101 may be sustained, so that a deformation and a forming of pockets or foldings are prevented.

[0091] Further referring to Fig.2, a level indicator 107 may be mounted to the top of the exterior membrane 101.

[0092] Fig. 3 shows a storage 100 with the exterior membrane 101, wherein elongated restraining elements 301 of an outer support structure 112 are mounted to the covering of the storage 100. The elongated restraining elements 301 are for example flexible ropes, belts or cables. The elongated restraining elements 301 are mounted over the exterior membrane 101, so that the exterior membrane 101 is alignable at the support structure when the exterior membrane 101 expands due to the gas pressure in the storage volume V_s exceeding a predetermined pressure value. Hence, the exterior membrane 101 may be reinforced by the elongated restraining elements 301 of the outer support structure 112.

[0093] The elongated restraining elements 301 may form various patterns and may comprise different extension directions. As shown in Fig. 3, the exterior membrane 101 forms e.g. a hollow half ball shape, wherein the elongated restraining elements 301 run along great circles along the half ball shape and cross each other in one point, in particular at the top level of the exterior membrane 101, where the level indicator 107 is installed. Hence, the angle α between the two crossing elongated restraining elements 301 may be defined by e.g. approximately 10° to approximately 90° degree.

[0094] Fig. 4 shows a different run of the elongated restraining elements 301 in comparison to the run of the elongated restraining elements 301 of Fig. 3. The crossing elongated restraining elements 301 comprise an angle α between each other of for example approximately 40° to approximately 140° .

[0095] It should be noted that the term "comprising" does not exclude other elements or steps and "a" or "an" does not exclude a plurality. Also elements described in association with different embodiments may be combined. It should also be noted that reference signs in the

claims should not be construed as limiting the scope of the claims.

List of reference signs:

[0096]

100 storage
 101 exterior membrane
 101a exterior membrane in an expanded condition
 101b exterior membrane in an unexpanded condition
 102 interior membrane
 103 ground plate
 104 side wall
 105 support gas supply unit
 106 inner support structure
 107 level indicator
 108 gas supply unit
 109 biomass
 110 first mounting point
 111 second mounting point
 112 outer support structure

 301 elongated restraining element

 501 conventional exterior membrane

 502 conventional interior membrane

 503 inner volume

 504 outer volume

 505 blower

 506 level indicator

 507 inner support structure

 508 control valve

 509 rotating stirring devices

 601 conventional exterior membrane

 602 conventional interior membrane

 603 inner volume

 604 outer volume

 605 blower

 606 level indicator

 608 control valve

 610 ground

701 conventional exterior membrane

 711 leakage

 5 705 blower

 802 conventional interior membrane

 803 inner volume
 10 804 outer volume

 808 control valve

 15 812 leakage

 902 conventional interior membrane

 906 level indicator
 20 Vs storage volume

 Vs,o outer volume

 25 Vs,i inner volume

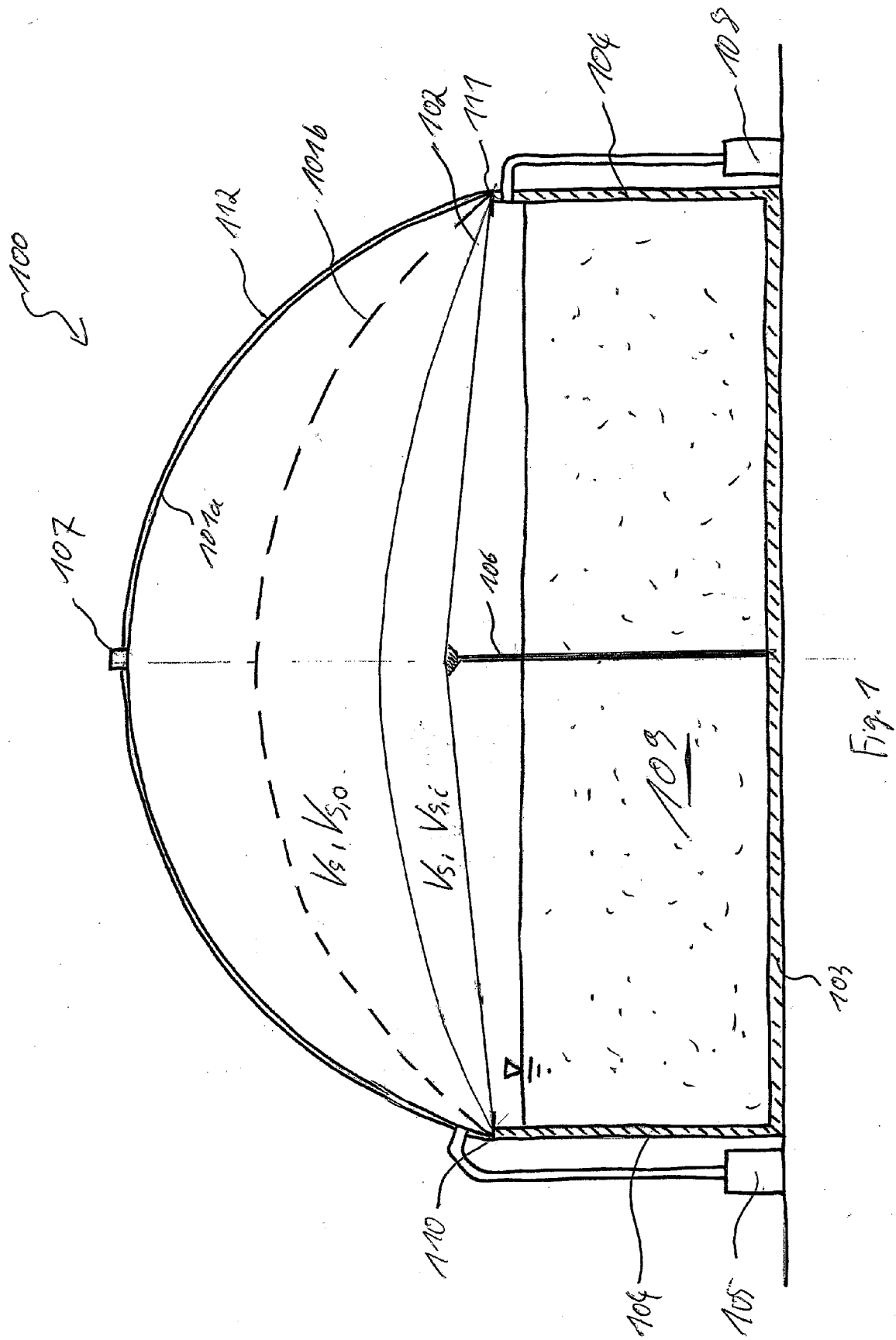
 α angle between two crossing elongated restraining elements

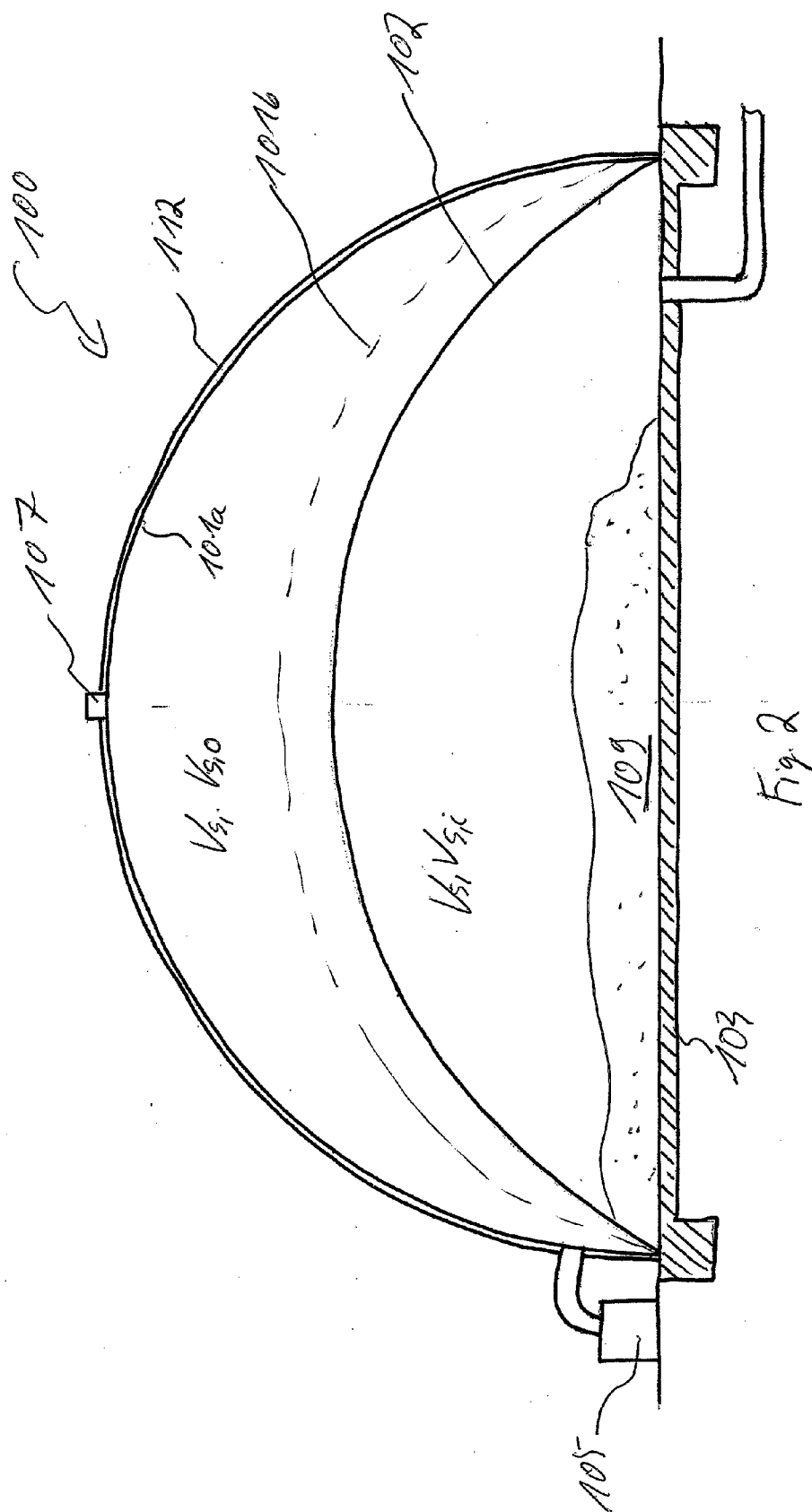
30

Claims

1. Covering for a gas storage (100), the covering comprising
 35 an interior membrane (102) which is mountable to the gas storage (100) for at least partially enveloping an inner volume (Vs,i) of the storage (100) for storing industrial gas,
 40 an exterior membrane (101) which is mountable to the gas storage (100), wherein the exterior membrane (101) covers the interior membrane (101) in such a way that an outer volume (Vs,o) for storing support gas is generated between the exterior membrane (101) and the interior membrane (102), and
 45 wherein the exterior membrane (101) comprises a material with an ultimate elongation of more than 100%.
2. Covering according to claim 1,
 50 wherein the exterior membrane (101) and/or the interior membrane (102) is formed in such a way that the exterior membrane (101) has a stretch ratio between an expanded condition of the exterior membrane (101) in a regular operating condition and a
 55 force-free unexpanded condition of the exterior membrane (101) of more than 1,1.
3. Covering according to claim 1 or 2,

- wherein the exterior membrane (101) and/or the interior membrane (102) is made of an elastomeric material, so that a shape and an area size of the exterior membrane (101) and/or the interior membrane (102) is adaptable to a pressure of the gaseous medium in the outer volume ($V_{s,o}$).
4. Covering according to one of the claims 1 to 3, wherein the material of the exterior membrane (101) and/or the interior membrane (102) is an elastomeric or a thermoplastic elastomer, in particular a synthetic rubber.
 5. Covering according to claim 4, wherein the material of the exterior membrane (101) and/or the interior membrane (102) is ethylene propylene diene monomer.
 6. Covering according to one of the claims 1 to 5, wherein the interior membrane (102) comprises a material with an ultimate elongation of more than 100%.
 7. Covering according one of the claims 1 to 6, further comprising an outer support structure (112) which is mounted over the exterior membrane (101), so that the exterior membrane (101) is alignable at the outer support structure (112) when the exterior membrane (101) forms a predetermined shape and/or expands due to the support gas pressure in the outer volume ($V_{s,o}$) exceeding a predetermined pressure value.
 8. Covering according to claim 7, wherein the outer support structure (112) comprises elongated restraining elements (301), particularly cables, belts, ropes or a mesh.
 9. Gas storage for an industrial gas, the gas storage comprising the covering as set forth in one of the claims 1 to 8, wherein the interior membrane (102) is mounted to the gas storage (100) for at least partially enveloping the inner volume ($V_{s,i}$), and wherein the exterior membrane (101) is mounted to the gas storage (100) wherein the exterior membrane (101) covers the interior membrane (101) in such a way that an outer volume ($V_{s,o}$) for storing support gas is generated between the exterior membrane (101) and the interior membrane (102).
 10. Gas storage (100) according to claim 9, further comprising a ground plate (103), and a side wall (104) mounted to the ground plate (103), wherein the exterior membrane (101) and the interior membrane (102) are mounted to the side wall (104).
 11. Gas storage (100) according to claims 9 or 10, further comprising a support gas supply unit (105) which is installed in such a way that the support gas is supplied into the outer volume ($V_{s,o}$) for adjusting a predetermined support gas pressure in the outer volume ($V_{s,o}$).
 12. Method of manufacturing a storage (100) for a gaseous medium, the method comprising mounting an interior membrane (102) to the gas storage (100) for at least partially enveloping an inner volume ($V_{s,i}$) of the gas storage (100) for storing industrial gas, and mounting an exterior membrane (101) to the gas storage (100), wherein the exterior membrane (101) covers the interior membrane (101) in such a way that an outer volume ($V_{s,o}$) for storing support gas is generated between the exterior membrane (101) and the interior membrane (102), wherein the exterior membrane (102) comprises a material with an ultimate elongation of more than 100%.
 13. Storage (100) for storing a gaseous medium, the storage (100) comprising an interior membrane (102) for at least partially enveloping an inner volume ($V_{s,i}$) into which industrial gas is storable, and a gas supply unit (108), which is connected to the inner volume ($V_{s,i}$) for supplying support gas to the inner volume ($V_{s,i}$), so that a gas pressure in the inner volume ($V_{s,i}$) is prevented from falling below a predetermined nominal gas pressure and/or a position of the interior membrane (102) is prevented from falling below a predefined position limit.
 14. Storage (100) according to claim 13, wherein the storage (100) is a storage (100) as set forth in one of the claims 9 to 11.
 15. Use of a covering as set forth in one of the claims 1 to 8 or of a gas storage as set forth in one of the claims 9 to 11 as a bio gas storage.





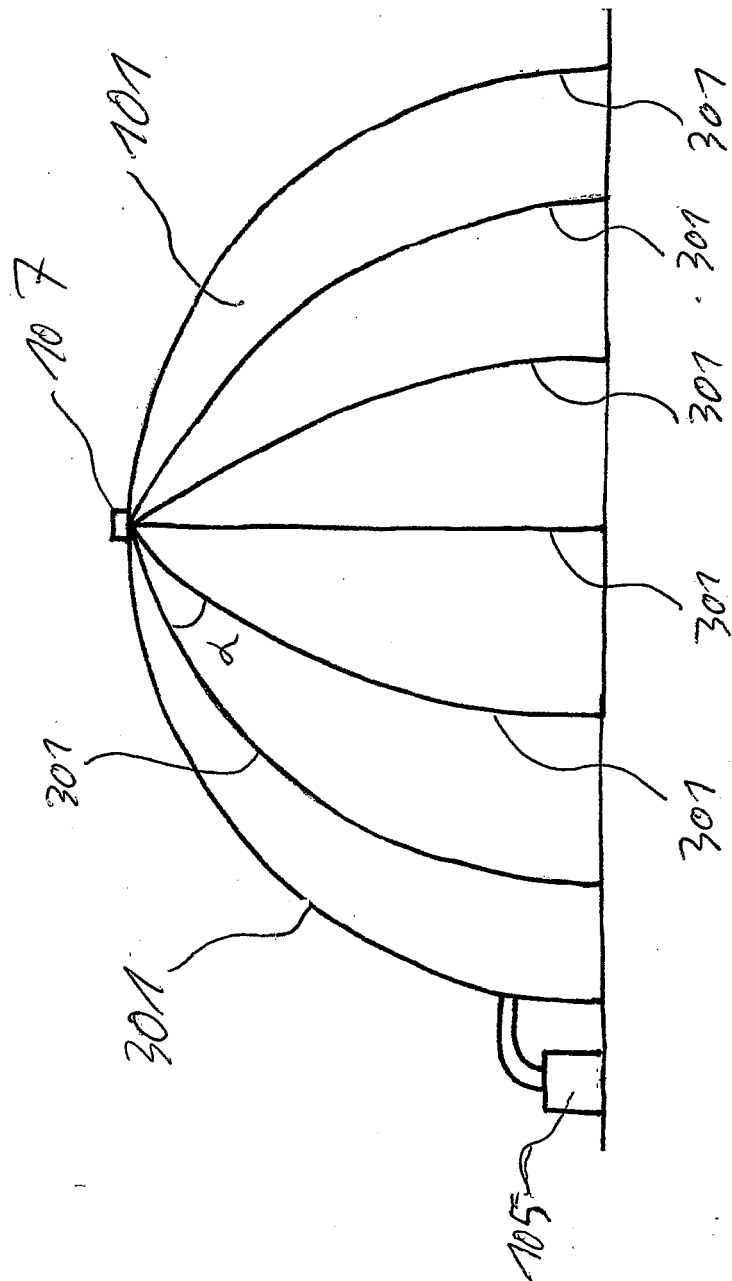


Fig. 3

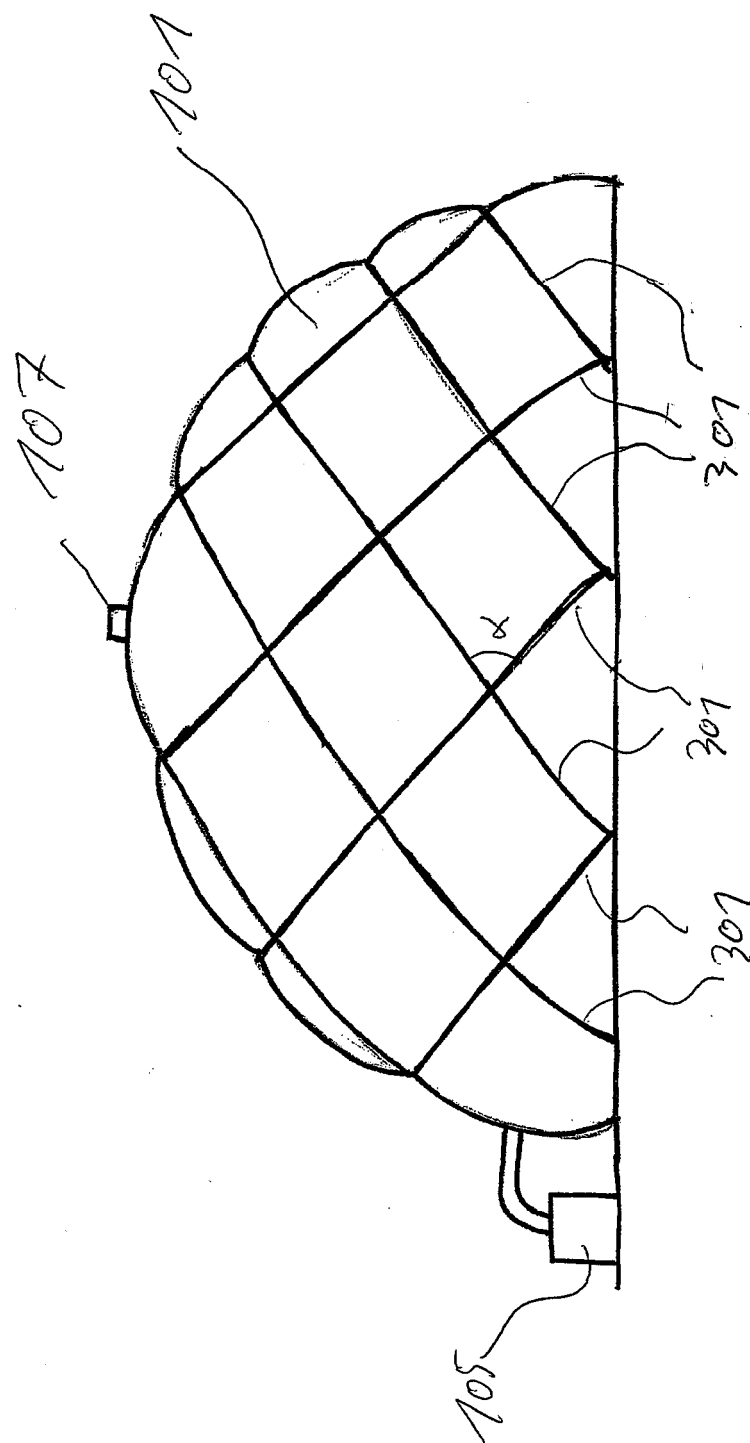


Fig. 4

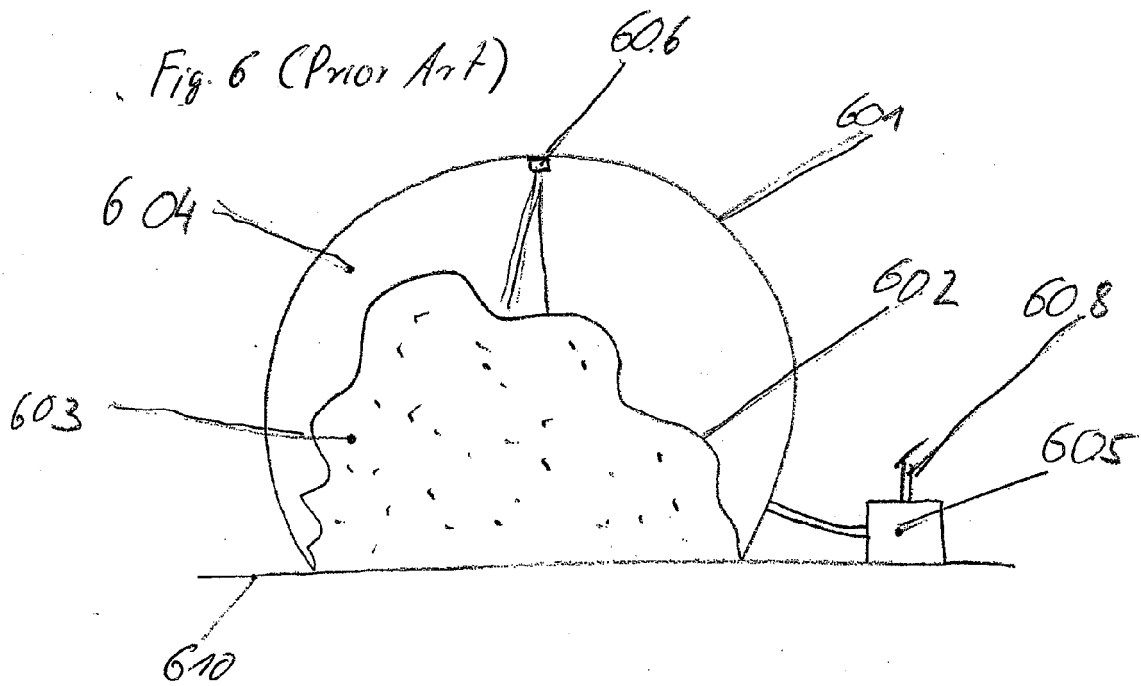
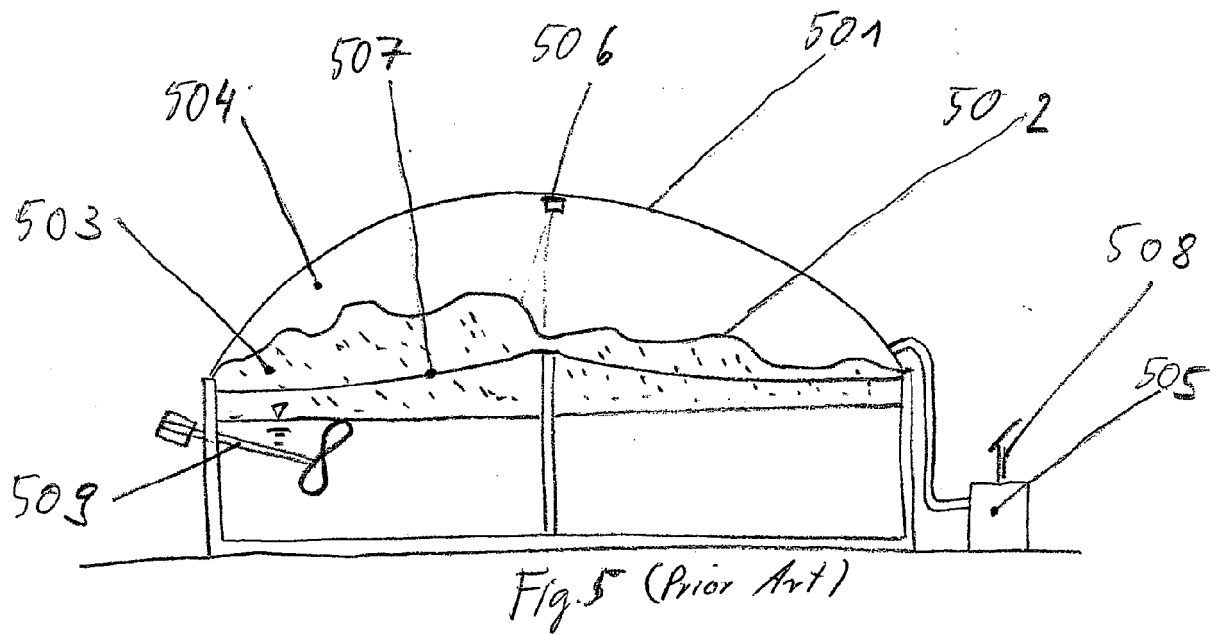


Fig. 7 (Prior Art)

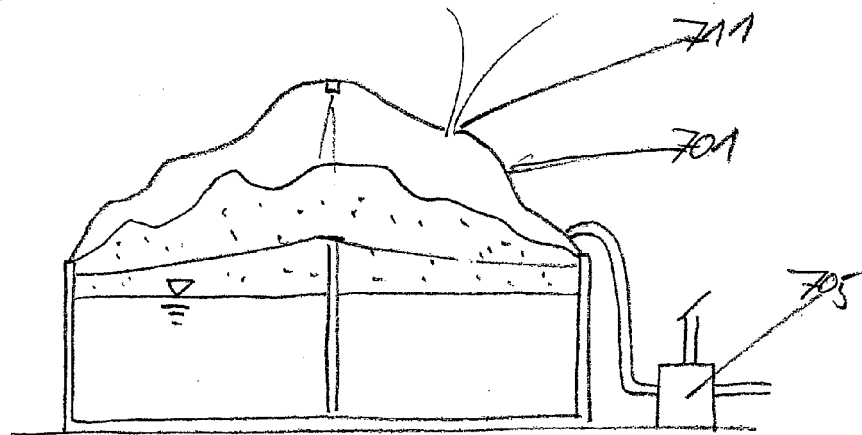
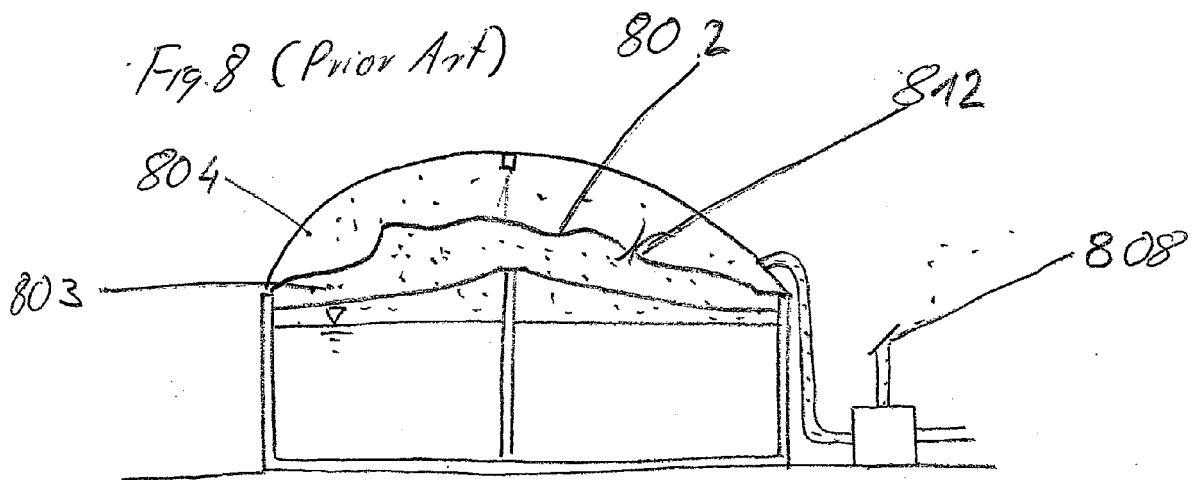
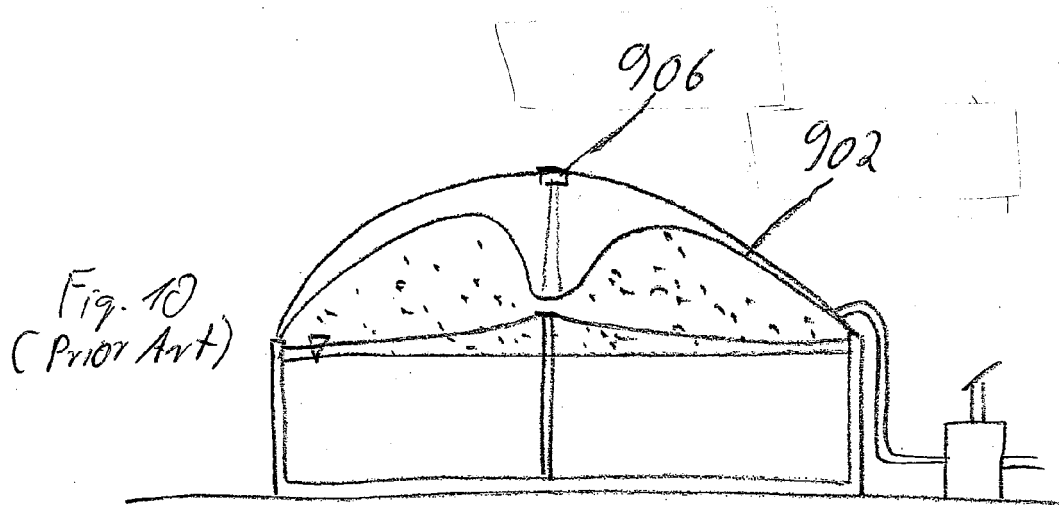
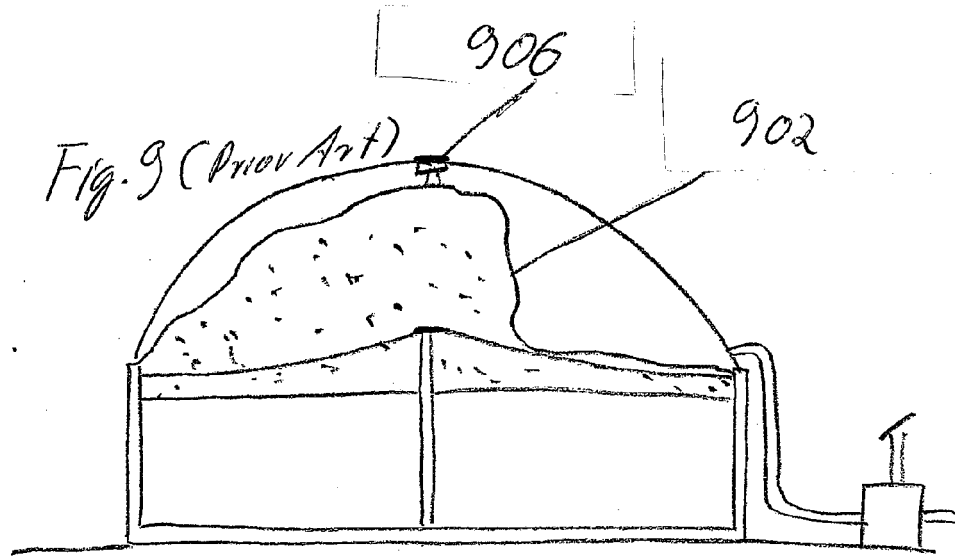


Fig. 8 (Prior Art)





**PARTIAL EUROPEAN SEARCH REPORT**

Application Number

under Rule 62a and/or 63 of the European Patent Convention.
This report shall be considered, for the purposes of
subsequent proceedings, as the European search report

EP 11 15 9665

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 0 333 698 A2 (SATTler TEXTILWERKE [AT]) 20 September 1989 (1989-09-20)	1-4,6,9,15	INV. F17C1/16
Y	* the whole document * * abstract *	5	

X	AT 388 158 B (SATTler TEXTILWERKE SATTler TEXTILWERKE [ST]) 10 May 1989 (1989-05-10)	1-4,6,9,10,12,15	
Y	* the whole document * * claim 1 *	5	

Y	DE 20 2005 011689 U1 (SCHMACK BIOGAS AG [DE]) 29 September 2005 (2005-09-29)	5	
	* paragraphs [0004], [0034], [0035] *		

Y	DE 10 2009 003696 A1 (CONTITECH ELASTOMER BESCH GMBH [DE]) 7 October 2010 (2010-10-07)	5	
	* paragraphs [0006], [0016] - [0022], [0037] *		

			TECHNICAL FIELDS SEARCHED (IPC)
			F17C
INCOMPLETE SEARCH			
The Search Division considers that the present application, or one or more of its claims, does/do not comply with the EPC so that only a partial search (R.62a, 63) has been carried out. Claims searched completely : Claims searched incompletely : Claims not searched : Reason for the limitation of the search: see sheet C			
Place of search		Date of completion of the search	Examiner
Munich		27 January 2012	Nicol, Boris
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			

 2
EPO FORM 1503 03.82 (P04E07)



**INCOMPLETE SEARCH
SHEET C**

Application Number
EP 11 15 9665

Claim(s) completely searchable:
1-12, 15

Claim(s) not searched:
13, 14

Reason for the limitation of the search:

No search of claims 13 and 14 according to the reply of the invitation pursuant to rule 62(a) 1 EPC.



Application Number

EP 11 15 9665

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☒ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

1-6, 9, 10, 12, 15

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).



**LACK OF UNITY OF INVENTION
SHEET B**

Application Number
EP 11 15 9665

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-6, 9, 10, 12, 15

A covering for a gas storage according to claim 1 with further mechanical details of the construction of the covering and of the gas storage as a membrane made of elastomeric material.

2. claims: 7, 8

A covering for a gas storage according to claim 1 with an outer support structure mounted over the exterior membrane, so that the exterior membrane is alignable at the outer support structure when the exterior membrane forms a predetermined shape and/or expands due to the support gas pressure in the outer volume exceeding a predetermined pressure value.

3. claim: 11

A covering for a gas storage according to claim 1 with a support gas supply unit.

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 11 15 9665

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

27-01-2012

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0333698 A2	20-09-1989	AT 391181 B CS 8901667 A2 DE 58906271 D1 EP 0333698 A2 ES 2047710 T3 HU 206299 B SK 277948 B6	27-08-1990 15-09-1991 13-01-1994 20-09-1989 01-03-1994 28-10-1992 13-09-1995
AT 388158 B	10-05-1989	NONE	
DE 202005011689 U1	29-09-2005	DE 202005011689 U1 EP 1746336 A1 US 2007023440 A1	29-09-2005 24-01-2007 01-02-2007
DE 102009003696 A1	07-10-2010	DE 102009003696 A1 EP 2414157 A1 US 2012009369 A1 WO 2010112249 A1	07-10-2010 08-02-2012 12-01-2012 07-10-2010