



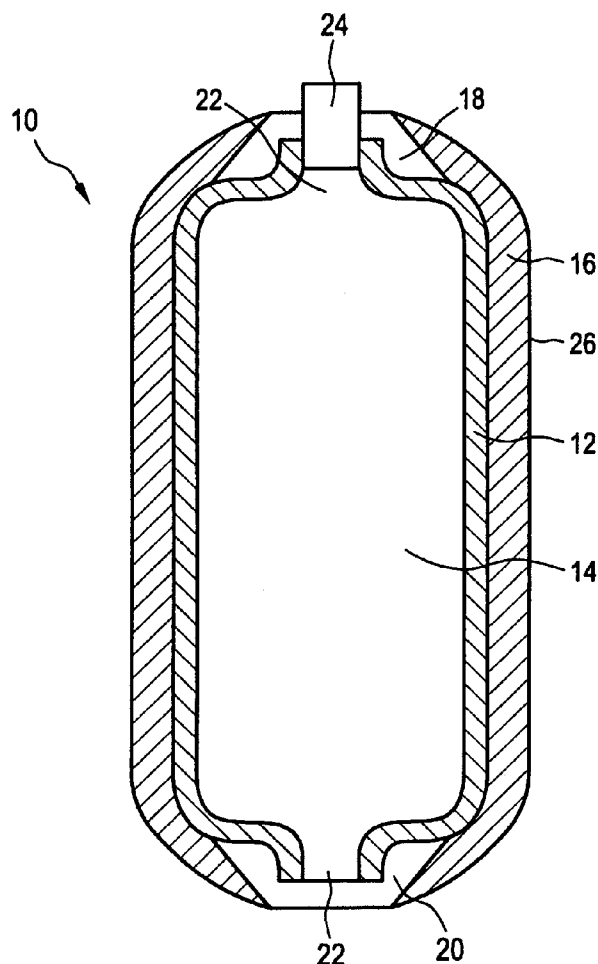
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Friedlmeier et al.(10) **Pub. No.: US 2012/0018314 A1**(43) **Pub. Date: Jan. 26, 2012**(54) **PRESSURE VESSEL FOR STORING
GASEOUS MEDIA UNDER PRESSURE**(30) **Foreign Application Priority Data**

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B65D 83/00 (2006.01)(52) **U.S. Cl.** **206/6**(57) **ABSTRACT**(73) Assignee: **Daimler AG,** Stuttgart (DE)(21) Appl. No.: **13/125,773**(22) PCT Filed: **Oct. 6, 2009**(86) PCT No.: **PCT/EP2009/007164**§ 371 (c)(1),
(2), (4) Date:**Jul. 7, 2011**

A pressure vessel for the storage of pressurized gaseous hydrogen includes a liner which defines an interior for the accommodation of the gaseous hydrogen and a wrapping encompassing the liner which gives the pressure vessel its dimensional stability. In order to prevent a discharge of gaseous hydrogen from the wrapping of the pressure vessel at a high rate if the pressure vessel is discharged after a prolonged downtime, the wrapping of the pressure vessel is designed to be at least partially gas-permeable, so that the gas penetrating through the liner can escape continuously through the wrapping of the pressure vessel.



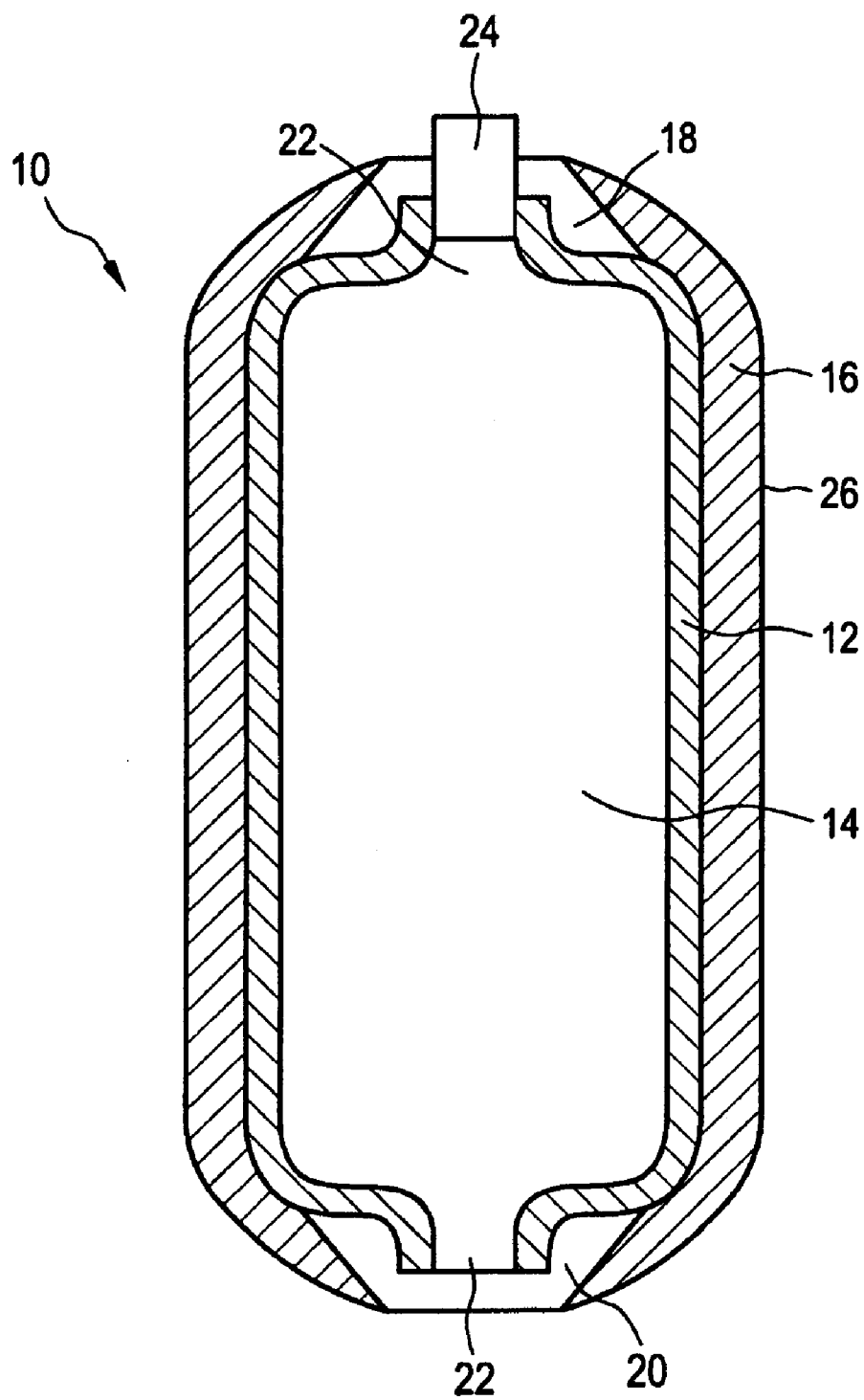


FIG. 1

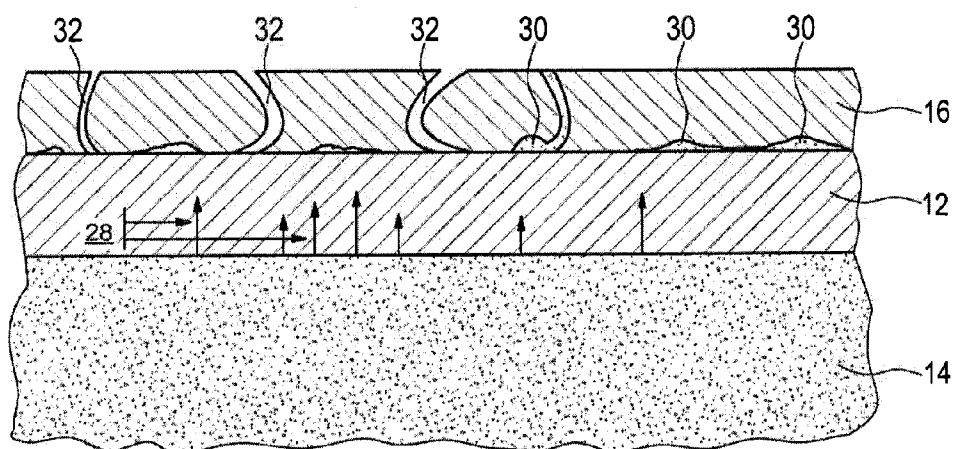


FIG. 2
PRIOR ART

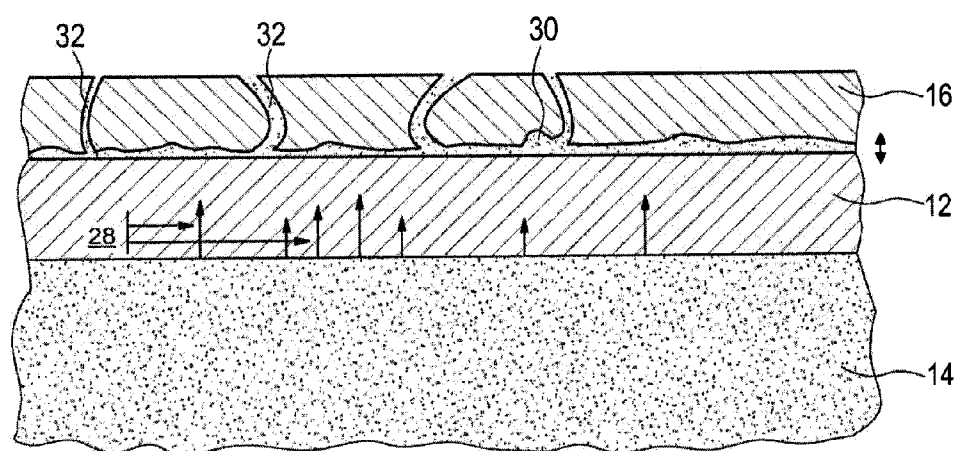


FIG. 3
PRIOR ART

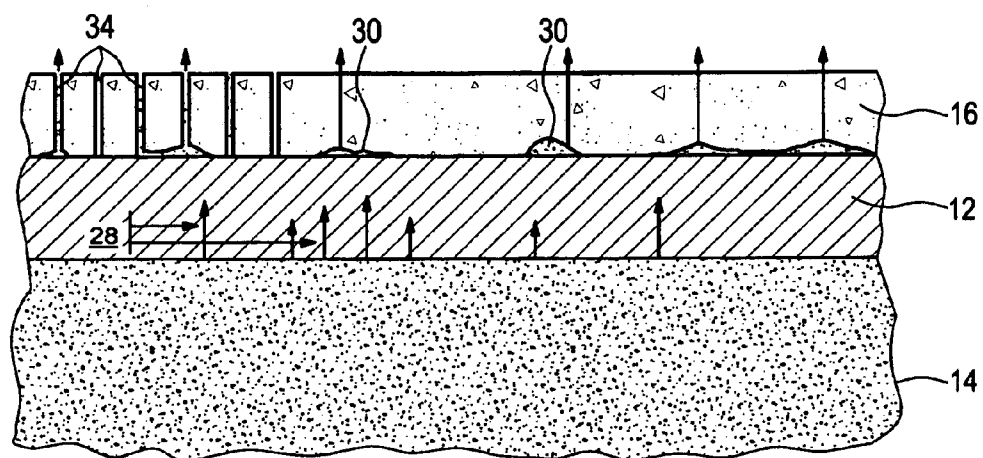


FIG. 4

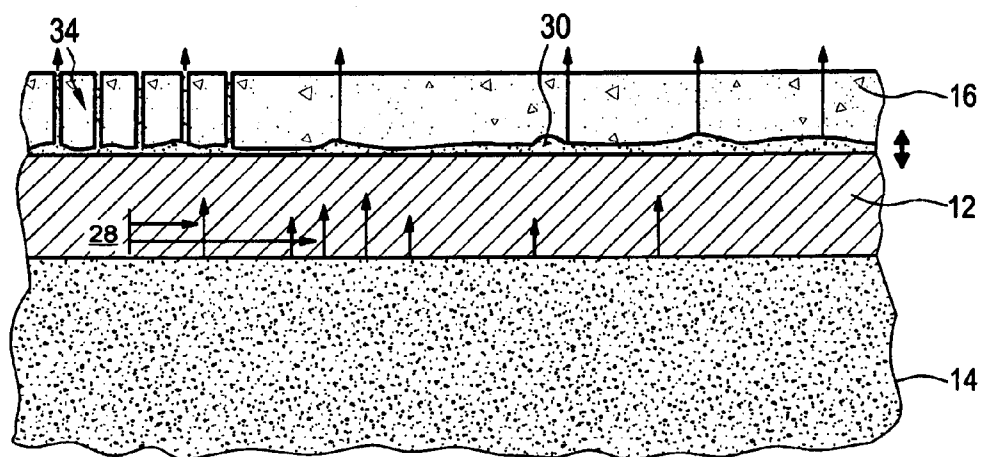


FIG. 5

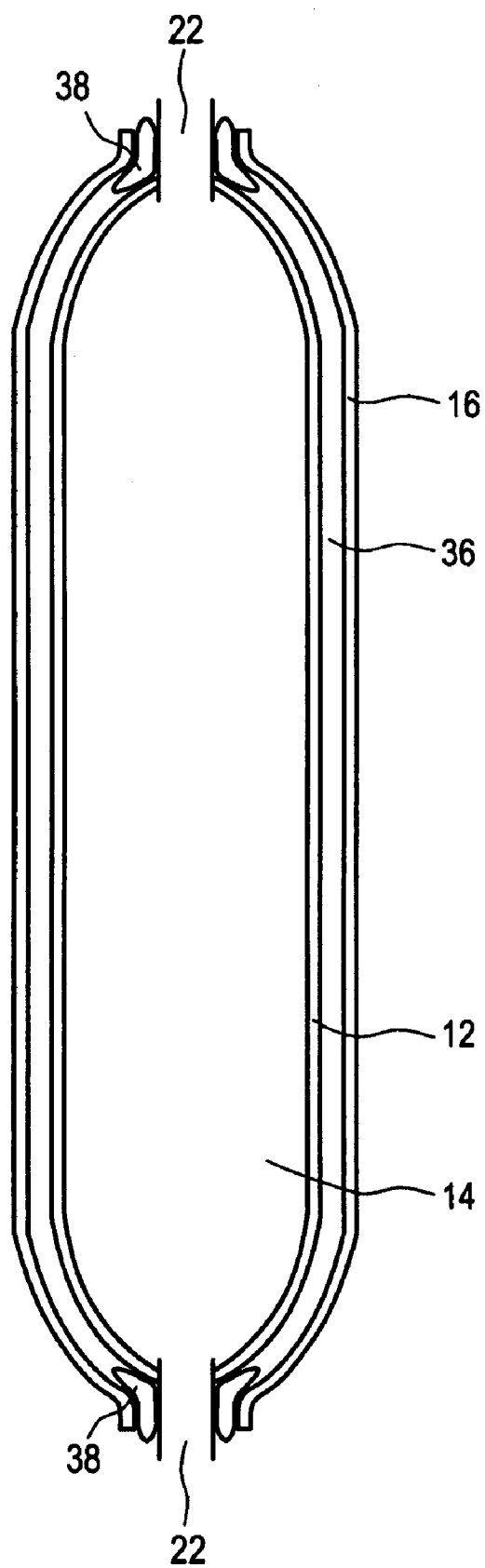


FIG. 6

PRESSURE VESSEL FOR STORING GASEOUS MEDIA UNDER PRESSURE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application is a national stage of PCT International Application No. PCT/EP2009/007164, filed Oct. 6, 2009, and claims priority under 35 U.S.C. §119 to German Patent Application No. 10 2008 053 244.4, filed Oct. 25, 2008, the entire disclosures of which afore-mentioned documents are herein expressly incorporated by reference.

BACKGROUND AND SUMMARY OF THE INVENTION

[0002] The invention relates to a pressure vessel for the storage of pressurized gaseous media. In particular, it relates to a pressure vessel of this type, including a liner which defines an interior for the accommodation of a gaseous medium and a wrapping encompassing the liner which gives the pressure vessel its dimensional stability.

[0003] Such generic pressure vessels, which are also referred to as composite pressure vessels, are known from EP 0 753 700 A1, for example. They comprise a liner defining an interior for the accommodation of a gaseous medium and a wrapping encompassing the liner, which gives the pressure vessel its dimensional stability. The liner is usually made of a plastic material, while the wrapping is produced from a fibrous composite material.

[0004] Pressure vessels of this type are for example used as hydrogen reservoirs in fuel cell systems and can store gaseous hydrogen at several hundred bars of excess pressure.

[0005] It has been observed that, in a discharge of such composite pressure vessels after a prolonged downtime, gaseous hydrogen escapes at a relatively high rate from the wrapping of the pressure vessel. There is therefore a demand for pressure vessels with a lower potential risk of hydrogen escape.

[0006] DE 33 08 276 A1 discloses a multilayer pressure vessel for hot hydrogen, wherein hydrogen which penetrates through the innermost metal layer of the wall is vented from the space between the innermost metal layers in order to prevent a hydrogen attack and/or an embrittlement problem in the outer metal layers of the wall of the vessel.

[0007] JP 2007-278482 A describes a composite pressure vessel with an inner tank and an outer tank. In order to protect the outer tank against attack by hydrogen penetrating through the inner tank and thereby to improve the durability of the pressure vessel, a continuous catalyst layer is provided between the inner and outer tanks, which converts the hydrogen into a stable compound.

[0008] The present invention provides a solution to the problem of creating a composite pressure vessel of the type referred to above which excludes any risk to the environment posed by gases escaping at excessively high rates.

[0009] This problem is solved by providing that an instantaneous escape of gaseous media at high rates during a discharge of the pressure vessel after a prolonged downtime is prevented by discharging gaseous media penetrating through the liner continuously and therefore at lower rates from the pressure vessel into the environment. The accumulation of gases penetrating through the liner in pockets between the liner and the wrapping and their instantaneous escape at high rates from the pressure vessel into the environment during a

discharge of the pressure vessel as a result of the separation between liner and wrapping are therefore avoided.

[0010] According to a first aspect of the invention, a pressure vessel for the storage of pressurized gaseous media comprises a liner which defines an interior for the accommodation of a gaseous medium and a wrapping encompassing the liner, which gives the pressure vessel its dimensional stability. According to the invention, the wrapping of the pressure vessel is designed to be at least partially gas-permeable, allowing the gas penetrating through the liner to escape from the pressure vessel through the wrapping.

[0011] This structure of the pressure vessel with an at least partially gas-permeable wrapping has the result that the gas penetrating through the liner can be discharged continuously and at low rates from the pressure vessel into the environment. In this way, the accumulation of the gas penetrating through the liner between the liner and the wrapping, and its instantaneous escape at high rates from the pressure vessel into the environment during a discharge of the pressure vessel, are prevented.

[0012] In a variant of the invention, the wrapping of the pressure vessel is designed to be at least partially porous. The wrapping of the pressure vessel may, for example, be made of a fibrous material bound with a resin material, the resin material being at least partially porous in the set state.

[0013] Alternatively or in addition, the wrapping of the pressure vessel is provided at predetermined points with holes which connect the interior of the wrapping to its outside.

[0014] In a further development of the invention, the wrapping of the pressure vessel is provided on its outside with a coating (e.g., layer of paint) which is likewise designed to be gas-permeable at least in the gas-permeable regions of the wrapping.

[0015] According to a second aspect of the invention, a pressure vessel for the storage of pressurized gaseous media comprises a liner which defines an interior for the accommodation of a gaseous medium and a wrapping encompassing the liner, which gives the pressure vessel its dimensional stability. According to the invention, a gas-permeable intermediate layer is provided between the liner and the wrapping, this being connected to the outside of the wrapping in at least one region, so that the gas penetrating through the liner can escape from the pressure vessel through the intermediate layer.

[0016] This structure of the pressure vessel with an at least partially gas-permeable intermediate layer between the liner and the wrapping has the result that the gas penetrating through the liner can be discharged continuously and at low rates from the pressure vessel into the environment. In this way, the accumulation of the gas penetrating through the liner between the liner and the wrapping, and its instantaneous escape at high rates from the pressure vessel into the environment during a discharge of the pressure vessel, are prevented.

[0017] In a variant of the invention, the intermediate layer is at least partially porous.

[0018] In a further development of the invention, a gas treatment device which may, for example, be formed by impregnating the intermediate layer with a gas treatment medium is provided in the connecting region between the intermediate layer and the outside of the wrapping.

[0019] The gas treatment device may for example comprise an oxidising catalyst. If the gaseous medium stored in the pressure vessel is hydrogen, the hydrogen flowing through

the liner and through the intermediate layer is oxidized to water by the oxidizing catalyst and can be discharged without endangering the environment.

[0020] In a further development of the invention, the connecting region between the intermediate layer and the outside of the wrapping is provided in the region of a neck of the pressure vessel. This may be the region of a filling and/or discharge opening of the pressure vessel.

[0021] The above and further features and advantages of the present invention are understood more easily from a perusal of the following description of preferred embodiments with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

[0022] FIG. 1 is a diagrammatic sectional view of a composite pressure vessel according to the present invention;

[0023] FIG. 2 is an enlarged part-section of a conventional composite pressure vessel before its discharge;

[0024] FIG. 3 is an enlarged part-section of a conventional composite pressure vessel after its discharge;

[0025] FIG. 4 is an enlarged part-section of a composite pressure vessel according to a first embodiment of the invention before its discharge;

[0026] FIG. 5 is an enlarged part-section of a composite pressure vessel according to a first embodiment of the invention after its discharge; and

[0027] FIG. 6 is a diagrammatic sectional view of a composite pressure vessel according to a second embodiment of the present invention.

DETAILED DESCRIPTION OF THE DRAWING FIGURES

[0028] The present invention is described below with reference to a pressure vessel for the storage of gaseous hydrogen at a pressure of, e.g., 700 bar, which may be used, for example, in fuel cell systems. The invention is, however, in no way restricted to this particular gaseous medium, this particular excess pressure in the interior of the pressure vessel and this particular application.

[0029] With reference to FIG. 1, the basic structure of a composite pressure vessel to which the present invention can be applied is described in greater detail below.

[0030] The composite pressure vessel 10 is formed from a liner 12 which defines an interior 14 for the accommodation of gaseous hydrogen. A plastic material may for example be used for the production of the liner 12. The liner 12 is surrounded by a wrapping 16 which may, for example, be made of a fibrous composite material such as resin-impregnated carbon fibers and which gives the pressure vessel 10 the necessary dimensional stability. The materials for the production of the liner 12 and the wrapping 16 are, however, not restricted to those mentioned above. In the same way, the invention is not restricted to a specific form of the wrapping 16 (e.g., axial and/or tangential and/or angled winding direction of the fibers) and to a specific thickness of the liner 12 and the wrapping 16. As the basic structure of the pressure vessel is known to the expert from prior art, the design of an embodiment fulfilling specific requirements (e.g., type of gas, pressure, application, etc.) will not pose any problems for him or her.

[0031] In the embodiment of FIG. 1, the pressure vessel 10 has two neck regions (on top and at the bottom in FIG. 1), each

of which is provided with an opening 22 sealed by a neck piece 18 and 20, respectively. In the opening 22 which is not sealed by a neck piece (on top in the figure), a valve 24 may be provided. The present invention is not restricted to a specific design of the neck pieces 18, 20. In addition, the two neck regions of the pressure vessel 10 may be provided with pole caps for the additional stabilization of the pressure vessel 10. The pressure vessel 10 may optionally be provided with two openings 22 fitted with valves 24. The shape of the pressure vessel 10 is moreover not restricted to that with two neck regions as shown in FIG. 1.

[0032] A coating 26, for example, a layer of paint, is further applied to the outside of the wrapping 16.

[0033] The problems of hydrogen escape from a conventional pressure vessel are explained below with reference to FIGS. 2 and 3.

[0034] In the interior 14 of the pressure vessel 10, gaseous hydrogen may, for example, be stored at a pressure of approximately 700 bar. In the course of time, a certain amount of this hydrogen is diffused through the liner 12 (see arrow 28 in FIG. 2). This gaseous hydrogen which has penetrated through the liner 12 largely accumulates in pockets 30 between the liner 12 and the wrapping 16. A small proportion of this hydrogen may reach the environment through pores or holes 32 in the wrapping 16. A free access of this accumulated hydrogen to the few small holes 32 in the wrapping is greatly impeded by a macroscopically flush contact between the wrapping 16 and the liner 12 at high pressure in the interior 14 of the liner 12.

[0035] After a prolonged downtime of the pressure vessel 10, the hydrogen in the pockets 30 between the liner 12 and the wrapping 16 causes a build-up of pressure which may in extreme cases result in a deformation of the liner 12.

[0036] If the pressure vessel 10 is then discharged after a prolonged downtime, or if a defined quantity of hydrogen is taken from the interior 14, so that the pressure in the interior 14 is reduced significantly, an excess pressure is created by the hydrogen accumulated in the pockets 30 between the liner 12 and the wrapping 16. As illustrated in FIG. 3, this excess pressure separates the liner 12 from the inside of the wrapping 16 and may also cause a deformation of the liner 12. This separation (see double-headed arrow in FIG. 3) creates a flow path for the gaseous hydrogen from the pockets 30 to the pores/holes 32 and thus to the outside of the wrapping 16, allowing hydrogen which has penetrated through the liner 12 to escape from the pressure vessel 10.

[0037] If the pressure vessel 10 is then discharged after a prolonged downtime, the hydrogen diffused through the liner 12 instantaneously flows from the pressure vessel 10 at a comparatively high rate.

[0038] In order to prevent a risk to the environment posed by the hydrogen escaping from the pressure vessel 10 at a high rate, the present invention proposes that the pressure build-up between the liner 12 and the wrapping 16 after a prolonged downtime of the pressure vessel 10, which has been described above, should be avoided. For this purpose various measures are taken within the scope of the present invention.

[0039] A first embodiment of a pressure vessel according to the invention is explained below with reference to FIGS. 4 and 5.

[0040] Like the conventional pressure vessel, the pressure vessel 10 of this embodiment comprises a liner 12 which defines an interior 14 for the accommodation of a gaseous

medium and a wrapping 16 encompassing the liner 12. In this design of the pressure vessel 10, during prolonged downtimes a high pressure in the interior 14 likewise causes the diffusion of a small quantity of hydrogen through the liner 12 (see arrows 28 in FIG. 4), the hydrogen initially accumulating in pockets 30 between the liner 12 and the wrapping 16.

[0041] In contrast to the conventional composite pressure vessels described above, however, the wrapping of the pressure vessel 10 of this embodiment is designed to be at least partially gas-permeable. For this purpose, the wrapping 16 may for example be porous. Alternatively or in addition, the wrapping 16 is provided at predetermined points with holes 34 which connect the interior of the wrapping 16 to its outside. In this way, the gaseous hydrogen penetrating through the liner 12 can be discharged continuously and at low rates through the wrapping 16 to the outside. Compared to the instantaneous release of the hydrogen at a high rate, the potential risk to the surroundings of the pressure vessel 10 posed by the escaping gaseous hydrogen is noticeably reduced.

[0042] Even if the liner 12 in this case separates slightly from the wrapping 16 as the pressure vessel 10 is discharged, creating flow paths between individual pockets 30 as shown in FIG. 5, large quantities of hydrogen are no longer released in this state, because the hydrogen has already been discharged evenly through the wrapping 16 over a long period of time and has not been able to build up any significant pressure between the liner 12 and the wrapping 16.

[0043] The wrapping 16 is designed to be gas-permeable at least in certain regions. In exemplary embodiments of the invention, however, the wrapping is designed to be gas-permeable substantially across all of its regions.

[0044] If, as FIG. 1 shows, the wrapping 16 is coated with a layer of paint 26 or the like, this layer of paint 26 will have to be gas-permeable as well in this embodiment. This applies at least to the regions in which the wrapping 16 is designed to be gas-permeable.

[0045] The porous wrapping 16 may for example be structured as follows. The wrapping 16 essentially consists of a fibrous composite material which may for example be made up from carbon fibers which give the wrapping its inherent compressive strength and of a resin for binding the carbon fibers. This resin has to be at least partially porous. The strength and stability under pressure of the wrapping 16 as a whole will nevertheless have to be ensured. The resin used for binding does not make any significant contribution to the stability of the pressure vessel 10 under pressure; the deciding factor is the carbon fiber bond.

[0046] To produce the porous wrapping 16, a resin may be used which, owing to high inner stresses, forms a sufficient number of micro-cracks in the setting process. These micro-cracks must, however, not result in a complete disintegration of the wrapping 16. In addition, the micro-cracks have to form a continuous connection through the entire wrapping 16, as they are required for the removal of the hydrogen into the environment.

[0047] The same conditions apply to any outer layer of paint 26 which may be provided. This can also be produced using the method described above and has to meet the same conditions with respect to hydrogen removal.

[0048] The provision of tailor-made holes 34 in sufficient numbers at points previously determined does not require any detailed explanation. In principle, any suitable methods may be used.

[0049] The gas-permeability of the wrapping 16 obviously varies with the gas in the interior 14 of the pressure vessel 10. Depending on the type of gaseous medium stored in the pressure vessel 10, the gas permeability characteristics, e.g., porosity and/or holes 34, will have to be adapted accordingly.

[0050] A second embodiment of a composite pressure vessel according to the present invention is described in greater detail below with reference to FIG. 6.

[0051] Like the conventional pressure vessel, the pressure vessel 10 of this embodiment comprises a liner 12 which defines an interior 14 for the accommodation of a gaseous medium and a wrapping 16 encompassing the liner 12. In this design of the pressure vessel 10 as well, during prolonged downtimes a high pressure in the interior 14 causes the diffusion of a small quantity of hydrogen through the liner 12.

[0052] In contrast to the conventional composite pressure vessels described above, the pressure vessel 10 of the embodiment shown in FIG. 6 is provided with a gas-permeable intermediate layer 36 between the liner 12 and the wrapping 16. This intermediate layer 36 may be connected to the outside of the wrapping 16, i.e., to the environment of the pressure vessel 10, in the neck regions (right-and left-hand side in FIG. 6) of the pressure vessel 10. In this way, the gaseous hydrogen which penetrates through the liner 12 can be discharged into the environment through the intermediate layer 36 continuously and at low rates. Compared to the instantaneous release of the hydrogen at a high rate, the potential risk to the surroundings of the pressure vessel 10 posed by the escaping gaseous hydrogen is noticeably reduced.

[0053] The wrapping 16 itself may be gas-tight like in conventional pressure vessels and optionally provided with a coating 26, for example a layer of paint. The intermediate layer 36 provided according to the invention is, for example, at least partially porous.

[0054] In addition, a gas treatment device 38 is provided in the connecting regions between the intermediate layer 36 and the surroundings of the pressure vessel 10, i.e., in the embodiment of FIG. 6 in the neck region of the pressure vessel 10 at the filling and/or discharge opening 22. This gas treatment device 38 may, for example, be produced by impregnating the porous intermediate layer 36 with a suitable gas treatment medium.

[0055] If gaseous hydrogen is to be stored in the interior 14 of the pressure vessel 10, this gas treatment device 38 may comprise an oxidizing catalyst which oxidizes the hydrogen in the connecting regions described above into water. The water produced in this way is discharged as a liquid or vapor while hydrogen flows after it through the intermediate layer 36. Any risk to the environment of the pressure vessel 10 posed by the discharge of hydrogen is completely avoided in this embodiment.

[0056] The oxidative catalytically-acting part 38 of the porous intermediate layer 36 is restricted to the region where the intermediate layer 36 emerges into the environment of the pressure vessel 10, where hydrogen would be discharged without the gas treatment device 38. The catalytically-acting region 38 may for example be produced by impregnating the porous intermediate layer 36 with a liquid which contains the catalyst in a dissolved or suspended form. By means of a thermal after-treatment of this impregnated region 38, the activity of the catalyst can be increased further. If the porous intermediate layer 36 has already been applied to the liner 12, such a thermal after-treatment has obviously to be restricted to temperatures which will not damage the liner 12.

[0057] As the oxidizing catalyst 38 is provided in the connecting region of the normal hydrogen outlet into the environment, there is sufficient access for the oxygen required for catalytic oxidation.

[0058] As the hydrogen penetrating through the liner 12 is discharged continuously, excess pressure does not develop between the liner 12 and the wrapping 16 while the pressure vessel is discharged and pressure is reduced in the interior 14 of the liner, so that an uneven deformation of the liner 12 is avoided.

[0059] In this context, a method for the application of the porous intermediate layer 36 to the liner 12 has to ensure that the free permeability of the porous intermediate layer 36 to hydrogen is maintained up to the catalytically-acting region 38 both in this process and during the subsequent application of the wrapping 16, in order to ensure that the hydrogen penetrating through the liner 12 is fed to the gas treatment device 38.

[0060] The same applies to the oxidising catalyst 38 at the free end of the porous intermediate layer 36, which may, for example, be produced by impregnation, in order to ensure an unimpeded discharge of the water produced in the catalyst 38 to the environment.

[0061] The foregoing disclosure has been set forth merely to illustrate the invention and is not intended to be limiting. Since modifications of the disclosed embodiments incorporating the spirit and substance of the invention may occur to persons skilled in the art, the invention should be construed to include everything within the scope of the appended claims and equivalents thereof.

1. A pressure vessel for storing pressurised gaseous media, comprising:

a liner that defines an interior for accommodation of a gaseous medium; and

a wrapping encompassing the liner that gives the pressure vessel dimensional stability,

wherein the wrapping of the pressure vessel is at least partially gas-permeable, so that the gaseous medium penetrates through the liner and escapes from the pressure vessel through the wrapping.

2. The pressure vessel according to claim 1, wherein the wrapping of the pressure vessel is at least partially porous and/or provided with holes (34) which connect the inside of the wrapping to its outside.

3. The pressure vessel according to claim 1, wherein the wrapping of the pressure vessel is made of a fibrous material bound with a resin material, the resin material being at least partially porous in the set state.

4. The pressure vessel according to claim 1, wherein the wrapping of the pressure vessel is provided with a coating on its outside, which is gas-permeable at least in the gas-permeable regions of the wrapping.

5. A pressure vessel for storing pressurised gaseous media, comprising:

a liner that defines an interior for accommodation of a gaseous medium; and

a wrapping encompassing the liner that gives the pressure vessel dimensional stability,

wherein a gas-permeable intermediate layer is connected to the outside of the wrapping in at least one region and is provided between the liner and the wrapping, so that the gaseous medium penetrates through the liner and escapes from the pressure vessel through the intermediate layer.

6. The pressure vessel according to claim 5, wherein the intermediate layer is at least partially porous.

7. The pressure vessel according to claim 5, wherein a gas treatment device is provided in a connecting region between the intermediate layer and the outside of the wrapping.

8. The pressure vessel according to claim 7, wherein the gas treatment device comprises an oxidising catalyst.

9. The pressure vessel according to claim 7, wherein the gas treatment device is produced by impregnating the intermediate layer with a gas treatment medium.

10. The pressure vessel according to claim 7, wherein the connecting region between the intermediate layer and the outside of the wrapping is provided in a region of a neck of the pressure vessel.

11. The pressure vessel according to claim 7, wherein the connecting region between the intermediate layer and the outside of the wrapping is provided in a region of a filling and/or discharge opening of the pressure vessel.

12. The pressure vessel according to claim 2, wherein the wrapping of the pressure vessel is provided with a coating on its outside, which is gas-permeable at least in the gas-permeable regions of the wrapping.

13. The pressure vessel according to claim 3, wherein the wrapping of the pressure vessel is provided with a coating on its outside, which is gas-permeable at least in the gas-permeable regions of the wrapping.

14. The pressure vessel according to claim 6, wherein a gas treatment device is provided in a connecting region between the intermediate layer and the outside of the wrapping.

15. The pressure vessel according to claim 8, wherein the gas treatment device is produced by impregnating the intermediate layer with a gas treatment medium.

16. The pressure vessel according to claim 8, wherein the connecting region between the intermediate layer and the outside of the wrapping is provided in a region of a neck of the pressure vessel.

17. The pressure vessel according to claim 9, wherein the connecting region between the intermediate layer and the outside of the wrapping is provided in a region of a neck of the pressure vessel.

18. The pressure vessel according to claim 8, wherein the connecting region between the intermediate layer and the outside of the wrapping is provided in a region of a filling and/or discharge opening of the pressure vessel.

19. The pressure vessel according to claim 9, wherein the connecting region between the intermediate layer and the outside of the wrapping is provided in a region of a filling and/or discharge opening of the pressure vessel.

20. The pressure vessel according to claim 10, wherein the connecting region between the intermediate layer and the outside of the wrapping is provided in a region of a filling and/or discharge opening of the pressure vessel.

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