

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
4 October 2007 (04.10.2007)

PCT

(10) International Publication Number
WO 2007/110399 A2

(51) International Patent Classification:
F17C 1/16 (2006.01)

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(21) International Application Number:
PCT/EP2007/052840

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(22) International Filing Date: 26 March 2007 (26.03.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/786,716 29 March 2006 (29.03.2006) US
06113077.9 25 April 2006 (25.04.2006) EP

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(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

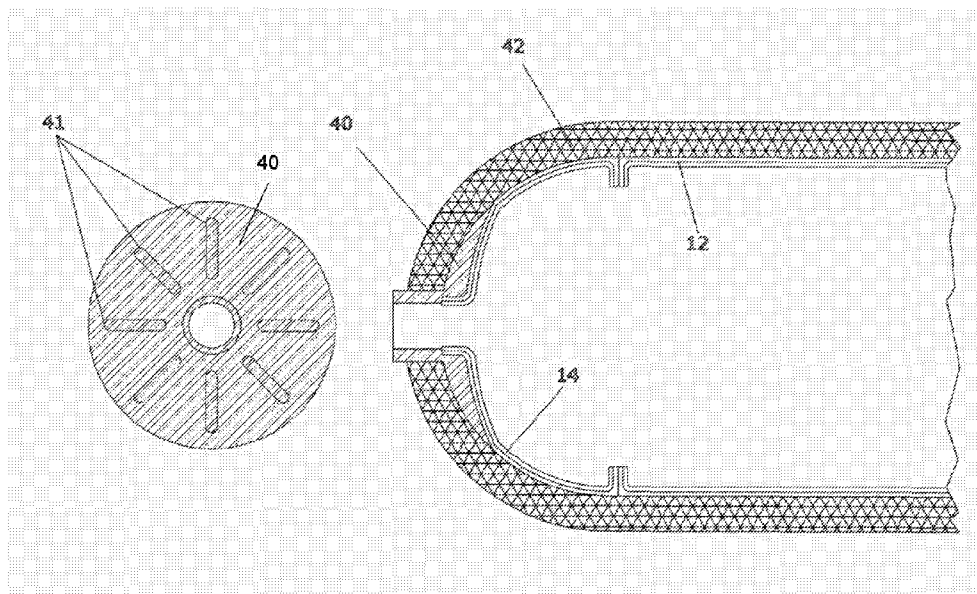
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Published:
— *without international search report and to be republished upon receipt of that report*

[Continued on next page]

(54) Title: METHOD FOR MANUFACTURING AN INNER LINER FOR A STORAGE TANK



(57) Abstract: A method for manufacturing a polymeric inner liner for a storage tank, in particular for a hydrogen storage tank, wherein the method comprises the steps of: providing a cylindrical body made from polymer material and comprising a structural layer and a barrier layer, said cylindrical body having a first open end and a first peripheral connection tab at said open end; providing a dome-shaped end cap made from polymer material, the end cap having a base with a cross-section essentially corresponding to a cross-section of the first open end of the cylindrical body and having a second peripheral connection tab at a peripheral end portion of said end cap; placing the end cap with its base onto the first open end of the cylindrical body and with said first and second peripheral tabs in contact with each other; and welding both connection tabs together. Storage tank made using such a liner and use of such a tank for storing hydrogen.

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Method for manufacturing an inner liner for a storage tank

This application claims priority to U.S. provisional application 60/786716 filed March 29, 2006 and incorporated herein by reference.

BACKGROUND OF THE INVENTION

5 The present invention relates to a method for manufacturing a polymeric inner liner for a storage tank, in particular for a hydrogen storage tank.

Compressed gas is becoming an increasingly popular choice for transportation fuels. As more and more vehicles use compressed gas as fuel, more emphasis needs to be put on the emissions of the fuel systems of such vehicles. Currently, there is a requirement from compressed gas fuel systems that
10 addresses the safety risks of gas permeation from such a system. There is, however, currently no standard that addresses the environmental concerns of compressed gas permeation. When such a standard is introduced, it is likely to be much more restrictive than the current emissions standard.

The vast majority of the compressed gas tanks used on transportation
15 vehicles today is designed to store compressed methane gas (CH₄) and is of type III or type IV. There is however, for environmental reasons, a desire to move to compressed hydrogen (H₂) as fuel. There are currently no production vehicles being fueled by compressed hydrogen.

Because of the larger molecule size of methane, compared to hydrogen,
20 conventional type II, III and IV tanks meet the current permeation requirements when filled with compressed methane gas. For compressed hydrogen, these conventional tanks do however not necessarily meet the requirements, especially if, as expected, more restrictive requirements are introduced.

Storage tanks have been classified in different categories. Type II tanks
25 concern all steel tanks, which are generally rather heavy and therefore not favored in relation with vehicles. Type III tanks are composite tanks with aluminum liners. These tanks show excellent emission results but are rather expensive. Type IV tanks are composite tanks with polymer liners. Type IV tanks also have very good emission results but, compared to the type III tanks,
30 these tanks have the further advantage of being lighter and less expensive. Therefore, type IV tanks are the most likely candidates for compressed hydrogen storage tanks.

One example of a type IV storage tank is shown in US 5,429,845, which discloses a storage tank comprising a non-metallic inner liner made of plastic or other elastomers and manufactured in one piece by compression molding, blow molding, injection molding or any other generally known technique. The inner
5 liner has a generally cylindrical centre portion and a generally dome-shaped end portion with connections for a metallic communication boss. Another, similar storage tank is disclosed in US 5,476,189, wherein the inner liner has a generally hemispheroidal end section with connections for a metallic communication boss.

It is also known, namely from WO 03/031860, to manufacture a pressure
10 vessel having an outer reinforcing layer and an inner liner comprising hemispherical end caps butt welded on a cylindrical body. This structure has the advantage that metallic connecting parts (namely for fixing a valve allowing the introduction of a fluid under pressure in the container) can easily be over molded by the end caps while the cylindrical body can be obtained by conventional
15 molding techniques. However, such a liner is a monolayer polypropylene one, which leads to bad results in terms of permeability.

It has also been proposed, namely in DE 103 60 953, to use a similar structure (inner liner with outer glass or carbon fiber composite) but with a multilayer liner based on HDPE and EVOH which gives much better results in
20 terms of permeability. However, the method of fabrication of the liner disclosed in that document is rather complicated because the liner is made in one piece by multiple step injection molding.

Combining the teaching of both documents (i.e. choosing a liner having a cylindrical body and welded end caps, but where the cylindrical body is made of
25 a multilayer structure) would provide both an improved method for manufacturing an inner liner for a storage tank and an improved inner liner for getting an improved storage tank.

However, welding of multilayer structures generally lead to connection problems in the welding zone (namely in terms of mechanical performances and
30 permeability).

SUMMARY OF THE INVENTION

The present invention aims at solving that problem and provides a method for manufacturing a polymeric inner liner for a storage tank, in particular for a hydrogen storage tank, the method comprising the steps of:

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- providing a cylindrical body made from polymer material and comprising a structural layer and a barrier layer, said cylindrical body having a first open end and a first peripheral connection tab at said open end;
- 5 ▪ providing a dome-shaped end cap made from polymer material, the end cap having a base with a cross-section essentially corresponding to a cross-section of the first open end of the cylindrical body and having a second peripheral connection tab at a peripheral end portion of said end cap;
- 10 ▪ placing the end cap with its base onto the first open end of the cylindrical body and with said first and second peripheral tabs in contact with each other; and
- 15 ▪ welding both connection tabs together.

According to one aspect of the invention, a peripheral end portion of the end cap is provided with a peripheral connection tab for welding to a peripheral connection tab of the open end of the cylindrical body. Such a connection allows limiting the risk of permeability at the connection between the end cap and the cylindrical body and provides a strong mechanical connection.

By “connection tab” is meant an extension of the wall of the cylindrical body and the end cap respectively that allows both parts to be welded to each other on a substantial portion of one of their outer surfaces. Preferably, these tabs are bended inwards so that the external surfaces of both parts are welded together, giving a projection inwards which, through its configuration, gives a strong and impermeable connection.

The dimensions of the welding tab are preferably greater than the wall thickness of the outer shell, as to facilitate the fold over of the material, but sufficiently small enough to ensure that the mechanical properties of the weld are not significantly different than those of the rest of the liner, hereby mitigating the risk of failure due to a stress riser. Welding tabs with a length of at least twice the wall thickness, but not more than 5 or even 4 times the wall thickness of the liner, are a good compromise in that regard.

With such a method, an inner liner with good emission results can be more cost-effectively produced. It is not necessary to use a complex injection molding process to produce the entire inner liner. The conventional blow molding technique, which is well known in the field of regular fuel tanks, can be used for making the cylindrical body. Also, the present method provides an easy and effective solution for manufacturing inner liners of different lengths. Indeed, a dome-shaped end cap can be connected to a cylindrical body of any length to

form the completed inner liner. Furthermore, the inner liner according to the present method provides excellent permeation qualities and is suitable in connection with storage tanks for compressed hydrogen. Finally, the end caps may for instance be made by over molding the accessories required for the tank function(s) or by thermoforming existing parts and fixing said accessories (or
5 connecting parts therefore) on these thermoformed parts.

In the method according to the invention, the end cap is preferably also provided with at least one structural layer and at least one barrier layer. In both parts (cylindrical body and end cap), the barrier layer is preferably sandwiched
10 between two structural layers, as it is the case in conventional fuel tanks. The presence of a barrier layer in the entire liner of the invention further increases its permeation performances. As a consequence, a storage tank with an inner liner as manufactured using this preferred embodiment can be used to reduce the emissions from the storage tanks into the atmosphere. It also allows the storage
15 of gasses of smaller molecule size, as e.g. hydrogen.

An adhesive layer can be provided between the structural layer and the barrier layer for bonding the two (or 3) layers. The adhesive layer can be made of any material that is adhesive to both the structural layer and the barrier layer, such as e.g. adhesive modified LDPE for a PE/EVOH configuration as described
20 below.

Preferably, the structural layer comprises polyethylene (PE) or polyamide (PA).

The barrier layer preferably comprises ethylene vinyl alcohol copolymer (EVOH) and can have a thickness of less than 500 μm , possibly even less than
25 300 μm .

The cylindrical body can have a second open end opposite the first open end and comprising a peripheral connection tab as well, and the method can comprise the further steps of:

- providing a further dome-shaped end cap made from polymer material, the further end cap having a base with a cross-section essentially corresponding to a cross-section of the second open end of the cylindrical body and a peripheral connection tab;
30
- placing the further end cap with its base onto the second open end of the cylindrical body and with both connection tabs in contact with each other; and
- welding the further end cap onto the second open end of the cylindrical body by welding both connection tabs together.
35

The invention further concerns an inner liner manufactured according to the above method and a storage tank comprising such an inner liner.

This above described inner liner is indeed generally combined with an outer shell to provide a storage tank. The nature of the outer shell is any structure suitable for containing at least 10 bar of pressure. This can come in the form of a metallic structure or more preferably, a carbon fiber filament composite wound around the outside of the liner, and then, preferably, wound with a layer of a more impact resistant material. Preferably, the liner and the outer shell are coaxially adjacent to each other and, besides the mechanical constraint of the outer shell on the inner liner, the two are not connected and expand and contract at different rates.

As already explained above, at least one end cap of the tank (liner) is provided with a connection part (communication boss) allowing connection of an accessory (valve for instance) to the storage tank. This part preferably is a metallic part. It may be over molded with the end cap of the liner in the case the latter is injection molded. Alternatively, this part may be a separate part put on top of the end cap of the liner before wounding the carbon filament composite around the liner. This embodiment is preferred especially when the end cap is obtained by thermoforming. In that case, the outer surface of the end cap of the liner and the lower surface of the connection part are preferably provided with a corresponding relief (for instance: grooves and ridges) that prevents the connection part from rotating while winding the fiber composite layer.

Finally, the present invention also concerns the use of a tank as described above for storing hydrogen.

Further aspects of the invention may become apparent by referring to the detailed description of a preferred embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings form an integral part of the specification and are to be read in conjunction therewith. The detailed description of the invention is a non-limiting description of one preferred embodiment of the invention.

- Fig.1: is a schematic illustration of a top section of a polymeric inner liner manufactured in accordance with the principles of the present invention.
- Fig.2: is a cut view through the inner liner according to a first aspect of the invention.
- Fig.3: is a cut view through the inner liner according to a second aspect of the invention.

Fig.4: is a cut view through the inner liner according to a third aspect of the invention.

Fig.5: is a detailed view of a metallic communication boss according to a preferred embodiment of the invention, and of the way it is encapsulated
5 into a tank according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG.1, a top section of a polymeric inner liner is indicated generally at 10 and comprises a cylindrical body 12, a first end of which is shown in Fig.1, and a dome-shaped end cap 14.

10 The cylindrical body 12 comprises a first open end 16 and comprises a first peripheral connection tab 18.

The end cap 14 has a base and an apex, wherein the base has a second open end 19 and the apex has a communication opening 20 for forming a communication between the inner chamber of the storage tank and the exterior of
15 the storage tank. The end cap 14 comprises, at its base, a second peripheral connection tab 22.

The peripheral connection tabs 18, 22 are arranged in such a way that, when the end cap 14 is placed on the first end of the cylindrical body 12, the peripheral connection tabs 18, 22 are in alignment and can be connected by
20 welding. Once welded together, the cylindrical body 12 and the end cap 14 form an inner chamber 24 wherein compressed gas can be stored.

Due to the peripheral connection tabs 18, 22 the risk of gas leaking through the inner liner 10 at the connection between the cylindrical body 12 and the end cap 14 is reduced.

25 The inner liner 10 shown in Fig.2 comprises a barrier layer 26 sandwiched between a first and a second structural layer 28, 28' with adhesive layers 30, 30' arranged between the barrier layer 26 and the structural layers 28, 28'. The inner liner 10 shown in Fig.3 comprises a barrier layer 26 connected to a structural layer 28 via an adhesive layer 30. The inner liner 10 shown in Fig.4 comprises a
30 barrier layer 26 directly connected to a structural layer 28.

The structural layer 28, 28' can be made of PE and can have a thickness in the range between 1 and 8 mm. Another material that could e.g. be used for the structural layer is PA. The barrier layer 26 can be made of EVOH and can have a thickness in the range between 50 and 500 μm . The adhesive layer 30, 30' can
35 have a thickness in the range between 50 and 500 μm . The adhesive layer 30, 30' can be made of any material that is adhesive to both the structural layer and the

barrier layer, such as e.g. adhesive modified LDPE for the above PE/EVOH configuration. The overall thickness of the inner liner 10 is in the range between 2 and 17 mm.

Returning to Fig.1, the communication opening 20 in the apex of the end cap 14 cooperates with a metallic communication boss, schematically indicated and generally referred to by reference number 32, to create a communication passage between the interior of the storage tank and the exterior thereof. A valve (not shown) is generally installed in this communication passage. Through the communication passage, compressed gas can be fed into the storage tank and released therefrom.

Fig. 5 shows a metallic communication boss 40 having grooves 41 that interlock with corresponding ridges (not shown) on the end cap 14 of the liner. These grooves 41 prevent the rotation of said boss 40 when a composite fiber outer shell 42 is wound around the liner and hence, allow said boss 40 to merely rest (without fixation) on top of the end cap 14 during the winding.

While specific embodiments have been shown and described in detail to illustrate the principles of the present invention, it will be understood that the invention may be embodied otherwise without departing from such principles. For example, one skilled in the art will readily recognize from the above discussion and from the accompanying drawings and claims that various changes, modifications and variations can be made without departing from the spirit and scope of the invention as described in the following claims.

REFERENCE NUMBERS

10	polymeric inner liner
12	cylindrical body
14	dome-shaped end cap
16	first open end
18	first peripheral connection tab
19	second open end
20	communication opening
22	second peripheral connection tab
24	inner chamber
26	barrier layer
28	first structural layer
28'	second structural layer
30	adhesive layer

- 30' adhesive layer
- 32 schematic view of the metallic communication boss
- 40 detail of the metallic communication boss
- 41 grooves on said boss
- 5 42 outer shell

CLAIMS

1. A method for manufacturing a polymeric inner liner for a storage tank, in particular for a hydrogen storage tank, the method comprising the steps of:

- 5 ▪ providing a cylindrical body made from polymer material and comprising a structural layer and a barrier layer, said cylindrical body having a first open end and a first peripheral connection tab at said open end;
- 10 ▪ providing a dome-shaped end cap made from polymer material, the end cap having a base with a cross-section essentially corresponding to a cross-section of the first open end of the cylindrical body and having a second peripheral connection tab at a peripheral end portion of said end cap;
- placing the end cap with its base onto the first open end of the cylindrical body and with said first and second peripheral tabs in contact with each other; and
- welding both connection tabs together.

15 2. The method as claimed in claim 1, wherein the welding tabs are bended inwards so that the external surfaces of the cylindrical body and of the end cap are welded together.

20 3. The method according to any of the preceding claims, wherein the welding tabs have a length greater than the wall thickness of the liner but not more than 5 times the wall thickness of the liner.

 4. The method according to any of the preceding claims, wherein the cylindrical body is made by blow molding.

25 5. The method according to any of the preceding claims, wherein the end caps are molded over accessories required for the tank function(s) or are obtained by thermoforming existing parts and fixing such accessories (or connecting parts therefore) on these thermoformed parts.

 6. The method as claimed in any of the preceding claims, wherein the barrier layer comprises an ethylene vinyl alcohol copolymer (EVOH) and has a thickness of less than 500 μm .

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7. A method for manufacturing a storage tank using a liner obtained by the method of any of the preceding claims, wherein a carbon fiber filament composite is wound around the outside of the liner to create at least part of an outer shell.

5 8. The method as claimed in the preceding claim, wherein the liner and the outer shell are coaxially adjacent to each other and wherein the two are not connected so that they are able to expand and to contract at different rates.

9. The method as claimed in claim 7 or 8, wherein the tank is provided with a connection part allowing the connection of an accessory (valve for
10 instance) to the tank, this connection part being a separate part put on top of the end cap of the liner before wounding the carbon filament composite around it, and wherein the outer surface of the end cap of the liner and the lower surface of the connection part are provided with a corresponding relief that prevents the connection part from rotating while winding the fiber composite.

15 10. The use of a storage tank obtained by the method of any of claims 7 to 9 for storing hydrogen.

FIGURE 5

