



- (51) International Patent Classification: *F17C 3/02* (2006.01)
- (21) International Application Number: PCT/FI2016/050306
- (22) International Filing Date: 10 May 2016 (10.05.2016)
- (25) Filing Language: English
- (26) Publication Language: English
- (71) Applicant: **WÄRTSILÄ FINLAND OY** [FI/FI]; Tarhaajantie 2, 65380 Vaasa (FI).
- (72) Inventors: **MALYS, Marcin**; Luzycka Str 6e, 81-537 Gdynia (PL). **ADAMOWICZ, Maciej**; Luzycka Str 6e, 81-537 Gdynia (PL). **KOCZUR-GRAZAWSKA, Malgo-**  
**rzata**; Luzycka Str 6e, 81-537 Gdynia (PL). **SLUSARSKI, Grzegorz**; Luzycka Str 6e, 81-537 Gdynia (PL).
- (74) Agent: **BERGGREN OY**; P.O. Box 16 (Eteläinen Rautatiekatu 10 A), 00101 Helsinki (FI).
- (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(54) Title: TANK ARRANGEMENT

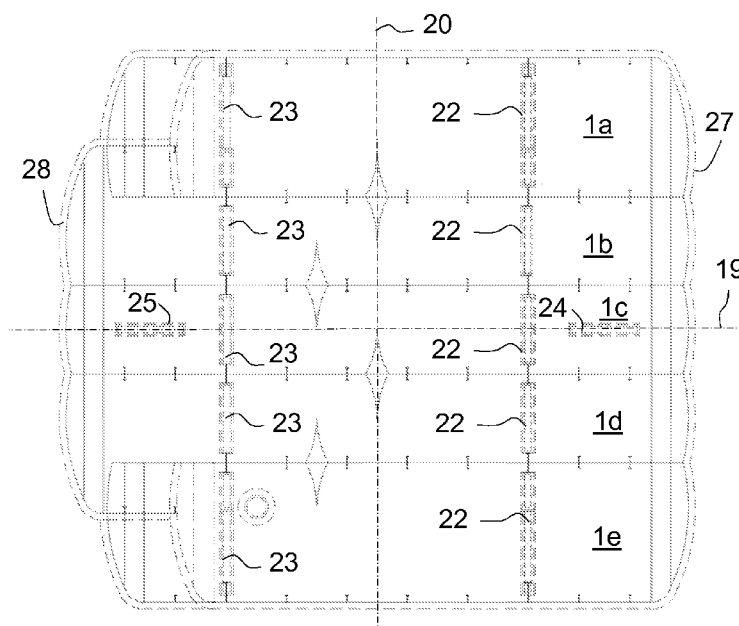


FIG. 7

(57) Abstract: The tank arrangement for storing liquefied natural gas comprises a multilobe tank (1) comprising at least three tank sections (1a, 1b, 1c, 1d, 1e) arranged in a row in the lateral direction, wherein each tank section (1a, 1b, 1c, 1d, 1e) is supported against a support surface (21) with a first support (22) allowing movement of the tank (1) relative to the support surface (21) in the longitudinal direction and with a second support (23), at least one of the second supports (23) preventing movement of the tank (1) relative to the support surface (21) in the longitudinal direction. One of the tank sections (1a, 1b, 1c, 1d, 1e) is further provided with a third support (24), which allows movement of the tank (1) relative to the support surface (21) in the longitudinal direction and prevents movement in the lateral direction, the first and second supports (22, 23) being configured to allow shrinkage and expansion of the tank (1) in the lateral direction.



**(84) Designated States** (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

**Published:**

— *with international search report (Art. 21(3))*

## Tank arrangement

### Technical field of the invention

The present invention relates to a tank arrangement for storing liquefied natural gas in accordance with claim 1.

5

### Background of the invention

Natural gas, or in general mixtures of hydrocarbons that are volatile enough to make the mixture appear in gaseous form in room temperature, constitutes an advantageous alternative to fuel oil as the fuel of internal combustion engines.

10 In sea-going vessels that use natural gas as fuel, the natural gas is typically stored onboard in liquid form, giving rise to the commonly used acronym LNG (Liquefied Natural Gas). Natural gas can be kept in liquid form by maintaining its temperature below a boiling point, which is approximately -162 degrees centigrade. LNG is usually stored at a pressure that is close to the atmospheric  
15 pressure, but large tanks used for storing LNG need to withstand significant hydrostatic pressures and a certain overpressure. For achieving good mechanical strength, LNG tanks are typically constructed as cylindrical or spherical containers. However, for practical reasons, large LNG tanks are sometimes designed as bilobe or multilobe tanks instead of cylindrical tanks. A bilobe tank  
20 comprises two mating curved halves, for instance two spherical caps or two cylindrical segments. A multilobe tank comprises at least three curved sections that are joined to each other. The sections can be partial cylinders or spheres.

Due to the low temperature needed for storing LNG, the dimensions of a tank that is in use and an empty tank that can be at a temperature of +30 °C can  
25 differ significantly from each other. This makes supporting of the LNG tanks challenging especially in ships, where it is important to firmly attach the tank to the hull of the ship.

### Summary of the invention

An object of the present invention is to provide an improved tank arrangement for storing liquefied natural gas. The characterizing features of the tank arrangement according to the invention are given in claim 1.

5 The arrangement according to the invention comprises a multilobe tank having a longitudinal axis defining a longitudinal direction and a lateral axis defining a lateral direction, the tank comprising at least three tank sections arranged in a row in the lateral direction, wherein each tank section is supported against a support surface with a first support allowing movement of the tank relative to  
10 the support surface in the longitudinal direction and with a second support, at least one of the second supports preventing movement of the tank relative to the support surface in the longitudinal direction. One of the tank sections is further provided with a third support, which allows movement of the tank relative to the support surface in the longitudinal direction and prevents movement in  
15 the lateral direction, the first and second supports being configured to allow shrinkage and expansion of the tank in the lateral direction.

With the tank arrangement according to the invention, expansion and shrinkage of the tank is allowed, but the tank is fixed to a supporting surface both in the longitudinal direction and the lateral direction.

20 According to an embodiment of the invention, all the second supports of the arrangement are configured to prevent movement of the tank relative to the support surface in the longitudinal direction. Longitudinal forces are thus carried by several supports.

25 According to an embodiment of the invention, each of the first supports allows movement of the tank in the lateral direction. This ensures that the tank can shrink and expand both in the lateral and the longitudinal direction. Alternatively, the first support of the tank section that is supported by the third support is configured to prevent movement of the tank in the lateral direction and the first supports of other tank sections are configured to allow movement of the tank in  
30 the lateral direction. One of the first supports can fix the tank in the lateral direction, and the tank can still expand and shrink in the lateral direction.

The second supports can be configured in a similar way. Thus, each of the second supports can allow movement of the tank in the lateral direction. Alter-

natively, the second support of the tank section that is supported by the third support can be configured to prevent movement of the tank in the lateral direction and the second supports of other tank sections can be configured to allow movement of the tank in the lateral direction.

- 5 According to an embodiment of the invention, the third support is arranged to support the centermost tank section. The tank thus shrinks symmetrically about the longitudinal center line of the tank and the center of gravity does not change.

- 10 According to an embodiment of the invention, the tank section that is provided with the third support is further provided with a fourth support which allows movement of the tank relative to the support surface in the longitudinal direction and prevents movement in the lateral direction. The fourth support prevents spinning of the tank about a vertical axis.

- 15 According to an embodiment of the invention, the first support and the second support are arranged between the third support and fourth support in the longitudinal direction. By placing the third support and the fourth support close to the ends of the tank, smaller lateral forces are needed for preventing the tank from spinning about a vertical axis.

- 20 The sea going vessel according to the invention comprises a tank arrangement defined above.

According to an embodiment of the invention, the longitudinal axis of the tank is parallel to the longitudinal axis of the vessel.

### **Brief description of the drawings**

- 25 Embodiments of the invention are described below in more detail with reference to the accompanying drawings, in which

Fig. 1 shows a cross-sectional view of a ship comprising an LNG tank arrangement,

Fig. 2 shows a top view of the tank arrangement of figure 1,

- 30 Fig. 3 shows a side view of the tank arrangement,

Fig. 4 shows a side view of the LNG tank with supports,

Fig. 5 shows a support for the tank,

Fig. 6 shows an end view of the tank, and

Fig. 7 shows a top view of the tank with supports.

5

### **Description of embodiments of the invention**

10 Figures 1 to 3 show an LNG tank arrangement of a ship 2. The arrangement comprises an LNG tank 1. The LNG tank 1 is a container that is configured to store liquefied natural gas. Natural gas is kept in liquid form by maintaining its temperature below a boiling point, which is approximately -162 degrees centi-  
grade. The LNG tank 1 is located in a tank hold 3, which is located around the longitudinal center line of the ship 2. The LNG tank 1 stores liquefied gas that is used as fuel in one or more engines of the ship 2.

15 The LNG tank 1 has a single shell structure. The space holding the LNG is formed by a shell 6 that is made of a cold resistant material. The expression "cold resistant material" refers to a material that can withstand the temperature of liquefied natural gas. Minimum design temperature of the material should be at most -165 °C. The material can be, for instance, stainless steel. Suitable materials are, for instance, 9 % nickel steel, low manganese steel, austenitic  
20 steels, such as types 304, 304L, 316, 316L, 321 and 347 and austenitic Fe-Ni alloy (36 % nickel). An insulation layer 7 is arranged around the shell 6. The insulation layer 7 can be made of, for instance, polyurethane.

25 The LNG tank 1 is a multilobe tank. The expression "multilobe tank" refers here to a tank that comprises at least three sections that have a curved cross-sectional profile and which are joined to each other such that the shell 6 of the tank 1 has an undulating shape at least on two sides. In the embodiment of the figures, the LNG tank 1 comprises five sections 1a, 1b, 1c, 1d, 1e each having the shape of a partial cylinder. The longitudinal center lines of the sections 1a, 1b, 1c, 1d, 1e are parallel to each other. The centermost section 1c has a  
30 shape that is formed by cutting a segment from a horizontal cylinder by two vertical planes. The other sections 1a, 1b, 1d, 1e each have a shape that is formed by cutting a segment from a horizontal cylinder by one vertical plane.

The sections 1a, 1b, 1c, 1d, 1e of the tank 1 are arranged in a row in a horizontal plane. The tank 1 has thus an undulating upper surface and an undulating lower surface. The outermost sections 1a, 1e are shorter than the three sections 1b, 1c, 1d in the middle of the LNG tank 1. The ends of the sections  
5 1a, 1b, 1c, 1d, 1e are closed by end caps 4a, 4b, 4c, 4d, 4e, 5a, 5b, 5c, 5d, 5e. The end caps can have a shape of a spherical cap or part of a spherical cap.

The tank 1 has a longitudinal axis 19 defining a longitudinal direction and a lateral axis 20 defining a lateral direction, which can be best seen in figure 7. The tank 1 has a first end 27 and a second end 28. The tank 1 is supported against  
10 a support surface 21, which can be formed by the hull of a ship 2, with supports that support the tank 1 in the vertical direction and also limit movements of the tank 1 in the horizontal plane. The support arrangement is described by referring in particular to figures 4 to 7.

Each section 1a, 1b, 1c, 1d, 1e of the tank 1 is supported against the support  
15 surface 21 with a first support 22 and a second support 23. The first support 22 is arranged closer to the first end 27 and the second support 23 is arranged closer to the second end 28 of the tank 1. The first supports 22 form a first row of supports and the second supports 23 form a second row of supports. Each of the first supports 22 and the second supports 23 has a curved upper surface  
20 that is adapted to the shape of the lower surface of the corresponding tank section 1a, 1b, 1c, 1d, 1e. Due to thermal expansion, the dimensions of the tank 1 may vary significantly. For instance, when the tank 1 is in use, its temperature should be approximately -162 °C. An empty tank 1 can have a temperature of +30 °C. To allow expansion and shrinkage of the tank 1, one row of  
25 supports is configured to allow movements of the tank 1 in the longitudinal direction. In the embodiment of the figures, the first supports 22 allow movements of the tank 1 in the longitudinal direction. The first supports 22 also allow movements of the tank 1 in the lateral direction, which allows expansion of the tank 1 in that direction. However, one of the first supports 22 could also fix the  
30 tank 1 in the lateral direction, and the tank 1 could still shrink and expand. The second supports 23 are configured to prevent movements of the tank 1 in the longitudinal direction. The position of the tank 1 is thus fixed in the longitudinal direction, although the first end 27 and the second end 28 are allowed to move in the longitudinal direction outwards from the fixing points defined by the sec-  
35 ond supports 23. It is not necessary that all the second supports 23 prevent movements of the tank 1 in the longitudinal direction, but it may be sufficient

that one of the second supports 23 prevents longitudinal movements of the tank 1. If only one of the second supports 23 prevents longitudinal movements, it is preferably the second support 23 supporting the centermost tank section 1c. If two or more second supports 23 prevent longitudinal movements, they  
5 are preferably arranged symmetrically about the longitudinal center line of the tank 1. All second supports 23, or all except one of the second supports 23, also allow movements of the tank 1 in the lateral direction. The tank 1 can thus freely expand in the lateral direction. One of the second supports 23 can fix the tank 1 in the lateral direction, but that is not necessary. If one of the second  
10 supports 23 and one of the first supports 22 fix the tank 1 in the lateral direction, they should support the same tank section.

The tank arrangement is further provided with a third support 24. The third support 24 allows movements of the tank 1 in the longitudinal direction but prevents movements in the lateral direction. The third support 24 thus fixes the  
15 tank 1 in the lateral direction. Since the lateral position of the tank 1 is fixed by the third support 24, all the first supports 22 and second supports 23 can allow movements of the tank 1 in the lateral direction. In the embodiment of the figures, the third support 24 is arranged to support the centermost tank section 1c. The position of the longitudinal center line of the tank 1 is thus stationary  
20 and the tank 1 expands and shrinks around the center line 1. This is advantageous especially in ships, since the position of the center of gravity of the tank 1 does not change.

In the embodiment of the figures, the tank arrangement is further provided with a fourth support 25. Also the fourth support 25 allows movements of the tank 1  
25 in the longitudinal direction but prevents movements in the lateral direction. The fourth support 25 is arranged to support the same tank section as the third support 24. The fourth support 25 ensures that the tank 1 does not spin about a vertical axis. The third support 24 is arranged close to the first end 27 of the tank 1 and the fourth support 25 is arranged close to the second end 28 of the  
30 tank 1. The first support 22 and the second support 23 are thus between the third support 24 and the fourth support 25 in the longitudinal direction of the tank 1. By placing the third support 24 and the fourth support 25 close to opposite ends 27, 28 of the tank 1, smaller lateral support forces are needed to prevent spinning of the tank 1 about the vertical axis.

Figure 5 shows an example of a support that can be used as the third support 24 or the fourth support 25. The support 24, 25 comprises a support element 30 that can be attached to the support surface 21. A rail 29 is supported against the support element 30 so that the rail 29 can move in the longitudinal direction of the support element 30. Lateral forces exerted on the rail 29 are carried by side supports 32 that are arranged on both sides of the rail 29. A reinforcement plate 31 is attached to an upper surface of the rail 29. The reinforcement plate 31 is attached to the bottom of one of the tank sections 1a, 1b, 1c, 1d, 1e. The reinforcement plate 31 is welded to the shell 6 of the tank 1 and functions as an additional reinforcement member.

It will be appreciated by a person skilled in the art that the invention is not limited to the embodiments described above, but may vary within the scope of the appended claims. For instance, the tank can comprise only three sections, or more than five sections.

## Claims

1. A tank arrangement for storing liquefied natural gas, the arrangement comprising a multilobe tank (1) having a longitudinal axis (19) defining a longitudinal direction and a lateral axis (20) defining a lateral direction, the tank (1) comprising at least three tank sections (1a, 1b, 1c, 1d, 1e) arranged in a row in the lateral direction, wherein each tank section (1a, 1b, 1c, 1d, 1e) is supported against a support surface (21) with a first support (22) allowing movement of the tank (1) relative to the support surface (21) in the longitudinal direction and with a second support (23), at least one of the second supports (23) preventing movement of the tank (1) relative to the support surface (21) in the longitudinal direction, one of the tank sections (1a, 1b, 1c, 1d, 1e) being further provided with a third support (24), which allows movement of the tank (1) relative to the support surface (21) in the longitudinal direction and prevents movement in the lateral direction, the first and second supports (22, 23) being configured to allow shrinkage and expansion of the tank (1) in the lateral direction.
2. A tank arrangement according to claim 1, wherein all the second supports (23) of the arrangement are configured to prevent movement of the tank (1) relative to the support surface (21) in the longitudinal direction.
3. A tank arrangement according to claim 1 or 2, wherein each of the first supports (22) allows movement of the tank (1) in the lateral direction.
4. A tank arrangement according to claim 1 or 2, wherein the first support (22) of the tank section that is supported by the third support (24) is configured to prevent movement of the tank (1) in the lateral direction and first supports (22) of other tank sections are configured to allow movement of the tank (1) in the lateral direction.
5. A tank arrangement according to any of the preceding claims, wherein each of the second supports (23) allows movement of the tank (1) in the lateral direction.
6. A tank arrangement according to any of claim 1 to 4, wherein the second support (23) of the tank section that is supported by the third support (24) is configured to prevent movement of the tank (1) in the lateral direction and the second supports (23) of other tank sections are configured to allow movement of the tank (1) in the lateral direction.

7. A tank arrangement according to any of the preceding claims, wherein the third support (24) is arranged to support the centermost tank section (1c).
8. A tank arrangement according to any of the preceding claims, wherein the tank section that is provided with the third support (24) is further provided  
5 with a fourth support (25) which allows movement of the tank (1) relative to the support surface (21) in the longitudinal direction and prevents movement in the lateral direction.
9. A tank arrangement according to claim 8, wherein the first support (22) and the second support (23) are arranged between the third support (24) and  
10 fourth support (25) in the longitudinal direction.
10. A sea going vessel (2) comprising a tank arrangement according to any of the preceding claims.
11. A sea going vessel (2) according to claim 10, wherein the longitudinal axis (19) of the tank (1) is parallel to the longitudinal axis of the vessel (2).

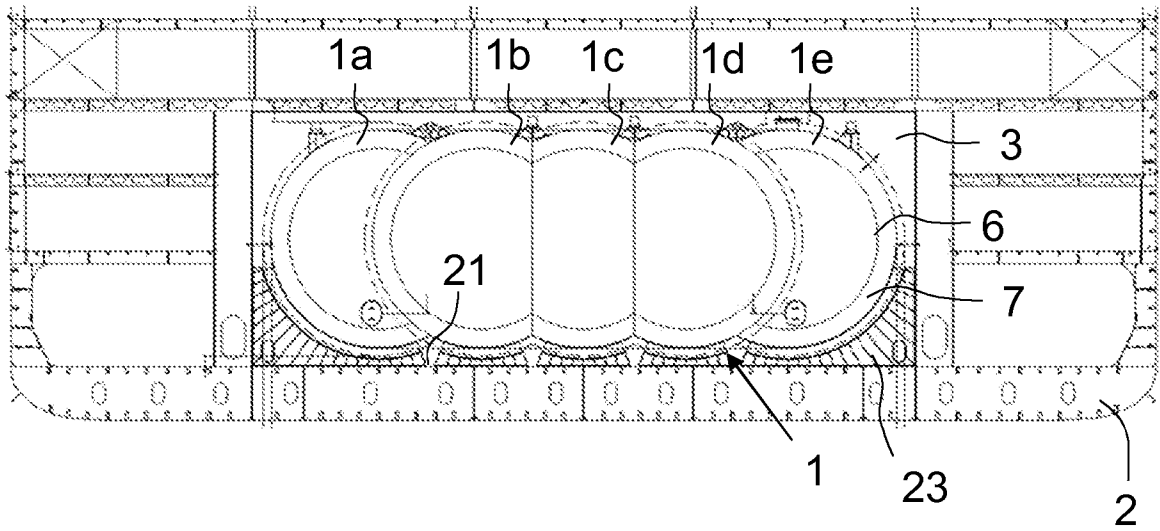


FIG. 1

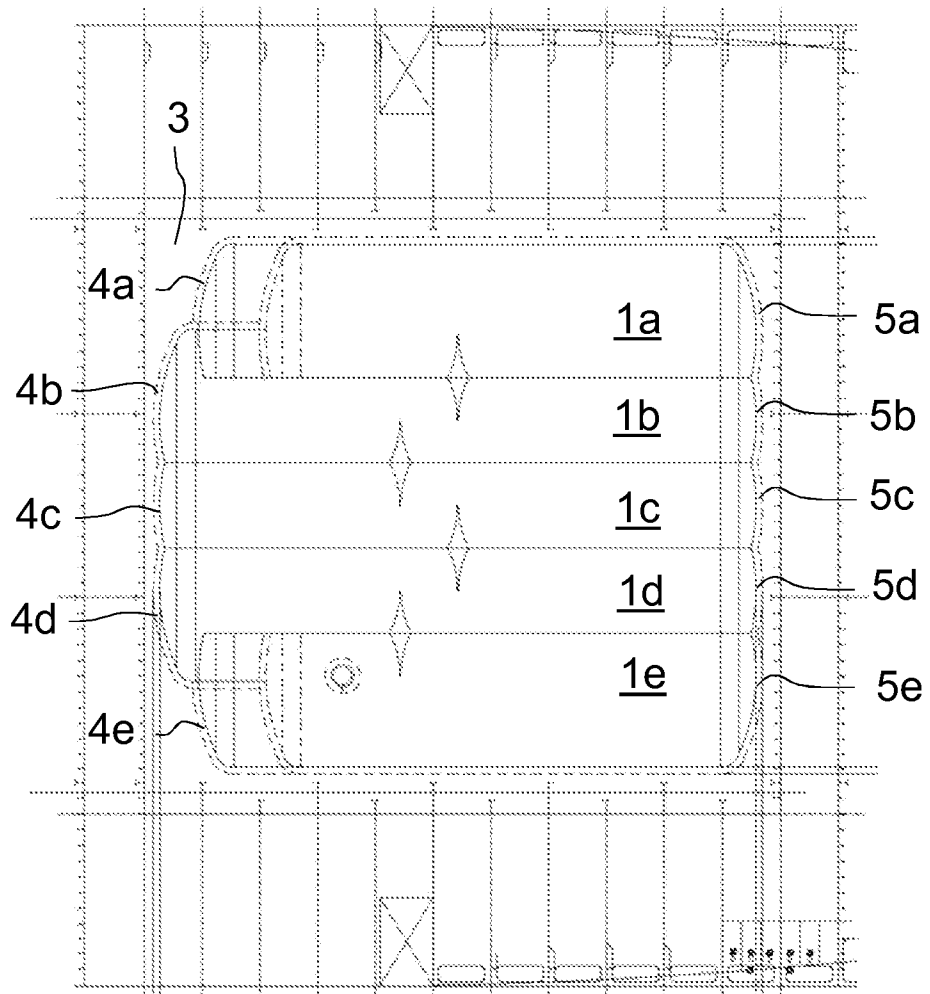


FIG. 2

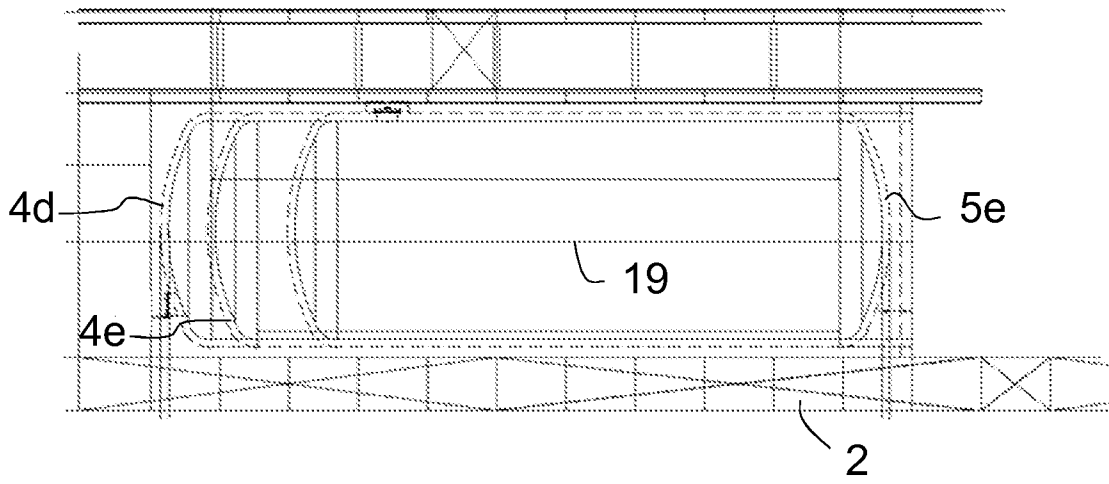


FIG. 3

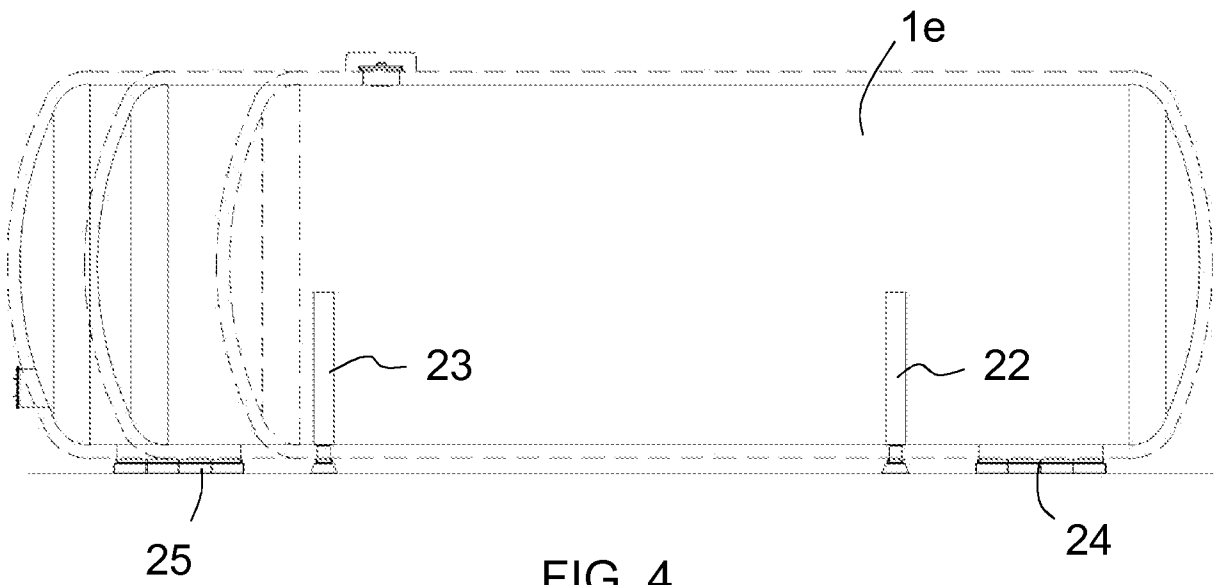


FIG. 4

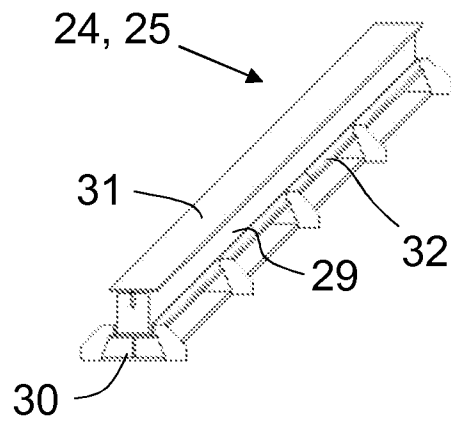


FIG. 5

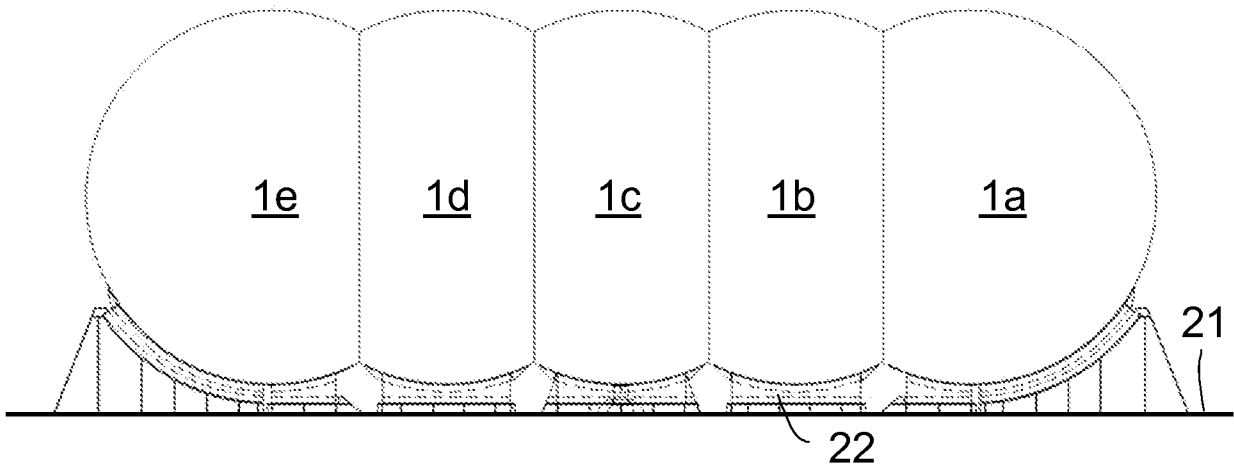


FIG. 6

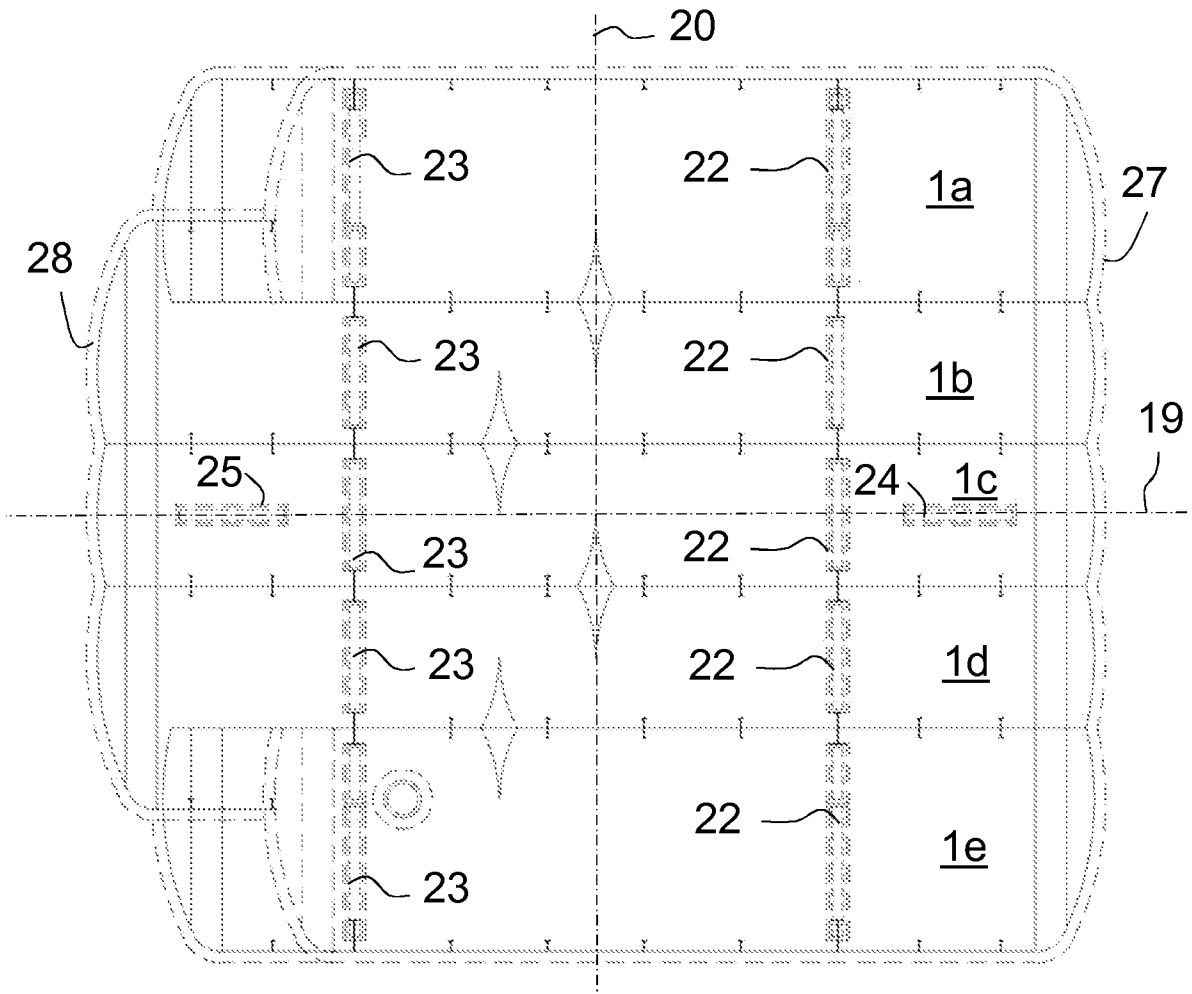


FIG. 7

**INTERNATIONAL SEARCH REPORT**

International application No  
PCT/FI2016/050306

**A. CLASSIFICATION OF SUBJECT MATTER**  
INV. F17C3/02  
ADD.  
  
According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**  
Minimum documentation searched (classification system followed by classification symbols)  
F17C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2007/062770 A2 (TGE GAS ENGINEERING GMBH [DE]; FRANK-TORSTEN APPEL [DE]) 7 June 2007 (2007-06-07) pages 6-10; figures 1-8 -----	1-11
X	WO 2010/006023 A2 (HOLLAND JOHN RANDOLPH [DE]; FICHELMANN WOLFGANG [DE]; WOLLERT JUERGEN) 14 January 2010 (2010-01-14) paragraphs [0022] - [0042]; claims 1,9,24; figures 1-6 -----	1-11
X A	GB 2 032 506 A (KVAERNER BRUG KJOLEAVDELNING) 8 May 1980 (1980-05-08) page 2; figures 4,11 -----	1-6,10, 11 7-9
A	US 4 182 254 A (SECORD CAMPBELL [GB]) 8 January 1980 (1980-01-08) columns 5,7; figures 1-4 -----	1-11

Further documents are listed in the continuation of Box C.

See patent family annex.

\* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search  20 January 2017	Date of mailing of the international search report  09/02/2017
--	--

Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer  Nicol, Boris
--	--

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No PCT/FI2016/050306
---

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2007062770	A2	07-06-2007	AT 423726 T 15-03-2009
			CN 101321662 A 10-12-2008
			DE 102005057451 A1 14-06-2007
			EP 1945498 A2 23-07-2008
			JP 4837046 B2 14-12-2011
			JP 2009517272 A 30-04-2009
			KR 20080093980 A 22-10-2008
			WO 2007062770 A2 07-06-2007
WO 2010006023	A2	14-01-2010	CN 102066190 A 18-05-2011
			EP 2293971 A2 16-03-2011
			JP 2011527656 A 04-11-2011
			KR 20110014652 A 11-02-2011
			KR 20130111649 A 10-10-2013
			US 2010012014 A1 21-01-2010
			US 2012255481 A1 11-10-2012
			WO 2010006023 A2 14-01-2010
GB 2032506	A	08-05-1980	NONE
US 4182254	A	08-01-1980	NONE