(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
17 September 2020 (17.09.2020)

WIPO | PCT

(10) International Publication Number
WO 2020/182294 A1

(51) International Patent Classification:
F17C 1/00 (2006.01)

(21) International Application Number:
PCT/EP2019/056115

(22) International Filing Date:
12 March 2019 (12.03.2019)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant: **WÄRTSILÄ FINLAND OY** [FI/FI]; Järvikatu 2-4, 65100 Vaasa (FI).

(72) Inventors: **WIDJESKOG, Klaus**; c/o Wärtsilä Finland Oy, Tarhaajantie 2, 65380 Vaasa (FI). **JANSSON, Mathias**; c/o Wärtsilä Finland Oy, Tarhaajantie 2, 65380 Vaasa (FI).

(74) Agent: **GENIP OY**; Heikinkatu 7, 48100 Kotka (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, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, 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.

(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).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

(54) Title: ARRANGEMENT FOR AND METHOD OF TRANSFERRING LIQUEFIED GAS FROM A CRYOGENIC TANK

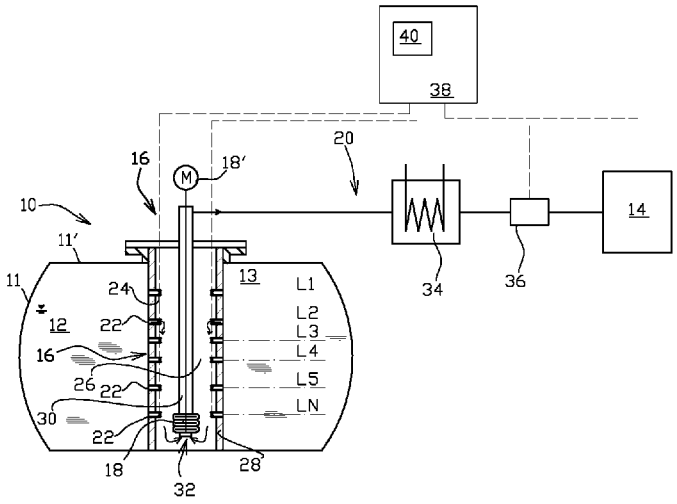

FIG. 1

(57) Abstract: Invention relates an arrangement for transferring liquefied gas from a cryogenic tank (11) comprising an intake passage (16) extending into the tank (11), a pump (18) arranged in connection with the intake passage (16) such that liquefied gas can be transferred from the cryogenic tank (11) into the intake passage (16) when the pump (18) is operated, wherein the intake passage (16) is provided with at least two inlet openings (22) arranged at different locations (L1...LN) of the intake passage (16), at least one of the inlet openings (22) is provided with a flow control means (24) configured to adjust the flow resistance of the inlet opening (22). Invention relates also to a method of transferring liquefied gas from a cryogenic tank (11).

WO 2020/182294 A1

[Continued on next page]

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

Arrangement for and method of transferring liquefied gas from a cryogenic tank

Technical field

[001] The present invention relates to an arrangement for transferring liquefied gas from a cryogenic tank according to the preamble of claim 1.

[002] The present invention relates also to a method of transferring liquefied gas from a cryogenic tank according to the preamble of the independent method claim.

Background art

[003] Liquefied gas as a fuel of prime movers in marine vessels and other mobile power plants has increasingly become of interest while the importance of environmental issues of particularly the exhaust emissions have increased.

[004] EP 2032428 B1 discloses an example of a fuel system for gas driven piston engine in a marine vessel, in which gas is stored in at least one fuel storage tank in the vessel as liquefied gas. The fuel feeding system comprises a separate fuel feed tank in which the gas is in liquid phase and at elevated pressure. The gas is also in liquid phase in the fuel storage tank, in which, however, prevails only the hydrostatic pressure caused by the liquid gas.

[005] As is generally known, gas may be transported in by special carrier ships via water ways to their destinations. When stored in liquefied form in a tank the gas is mainly in liquefied form at the bottom part of the tank but there is a gaseous space above the surface of the liquefied gas containing fractions of the gas. Gas cargo having different properties may be carried in the same tank if approved by the administration. This is mainly done to help operators and ship owners to save transportation cost and make some more profit from the same vessel by delivering different cargoes. When it comes to liquefied gas portion of the cargo tank,

the ship owners have to be extra cautious because of the various hazards associated with it. A so called Rollover is one such dangerous situation that can be generated while carrying liquefied gas cargo in large tanks.

[006] Rollover is a process of spontaneous mixing up of a similar or two different liquefied gas cargos due to changes in the density of upper and lower layers of liquefied gas in the tank. This can take place because of the boiling off of lighter fractions from the liquefied gas cargo, resulting in the liquid layer adjacent to the liquid surface to become denser than the layer beneath it. When this situation occurs, stratification develops and the unstable condition relieves itself with spontaneous mixing known as rollover. It has been commonly considered that the rollover phenomena have various negative effects. Due to the rollover the boil off rate may increase considerably because it facilitates transporting of lighter fractions to the upper layer, which result in more rapid increase of pressure in the tank.

[007] Patent application JP19920293027 proposes a solution to prevent the rollover phenomena. It proposes that rollover can be prevented by inserting a LNG distribution pipe, having double tube structure composed of an inner pipe with holes and an outer pipe with holes, in an LNG storage tank and rotating the inner pipe by a rotation mechanism. There is a pump by means of which LNG from a lower part of the tank is sucked into the inner pipe, and distributed to upper layer at vertical locations ruled by the holes to cause forced convection in the tank.

[008] An object of the invention is to provide an arrangement for and method of transferring liquefied gas from a cryogenic tank in which the stratification of the liquefied gas is made use in connection with transferring liquefied gas from a gas tank.

Disclosure of the Invention

[009] Objects of the invention can be met substantially as is disclosed in the independent claims and in the other claims describing more details of different embodiments of the invention.

[0010] According to an embodiment of the invention an arrangement for transferring liquefied gas from a cryogenic tank comprising an intake passage extending into the tank, a pump arranged in connection with the intake passage such that liquefied gas can be transferred from the cryogenic tank into the intake passage when the pump is operated, wherein the intake passage is provided with at least two inlet openings arranged at different locations of the intake passage, and wherein at least one of the inlet openings is provided with a flow control means configured to adjust the flow resistance of the inlet opening.

[0011] This way the stratification of the liquefied gas in the cryogenic tank is made use in connection with transferring liquefied gas from a gas tank e.g. to a gas consumer or other destination, so that the gas quality can be controlled and effected continuously. This provides also a method of controlling the fuel quality of the gas consumer and the operation of the gas consumer.

[0012] According to an embodiment of the invention the intake passage comprises a collector chamber and an intake conduit, wherein the intake conduit is configured to open inside the collector chamber and the collector chamber is provided with said at least two inlet openings arranged at different locations at the height of the collector chamber. The height means the dimension or location in the direction of liquefied gas normal in the tank. The direction of liquefied gas normal in the tank is also referred to as being vertical direction.

[0013] According to an embodiment of the invention the collector chamber comprises a duct and the intake conduit is arranged to extend parallel to the duct from a first end of the duct to the second end of the duct and that the intake conduit is provided with an inlet through which the intake conduit opens inside the duct at its second end.

[0014] According to an embodiment of the invention the intake conduit is inside the duct, wherein the collector chamber is arranged to an annular space between the intake conduit and the duct.

[0015] According to an embodiment of the invention the intake passage is provided with more than two inlet openings arranged at different locations at the

height of the passage, and each one of the openings is provided with a flow control means configured to adjust the flow resistance of the opening.

[0016] According to an embodiment of the invention the intake passage is arranged to a cryogenic tank such that is extends from a top wall of the tank to inside the tank in a below liquefied gas surface when the tank containing liquefied gas.

[0017] According to an embodiment of the invention the arrangement comprises at least one return conduit arranged such that the liquefied gas containing the mixture or composition in the intake passage can be returned back to the tank.

[0018] According to an embodiment of the invention the arrangement comprises at least two return conduits which into the tank at different vertical locations thereof.

[0019] The gas consumer may be for example an internal combustion engine or a fuel cell.

[0020] According to an embodiment of the invention the arrangement is in flow communication with a gas consumer configured to utilize the gas, such that the arrangement comprises a gas feed line extending from the intake passage to the gas consumer, wherein the arrangement further comprising a gas evaporator unit in the gas feed line for evaporating the liquefied gas into gaseous form and a gas monitoring unit in the gas feed line downstream the gas evaporator unit, and a controller unit arranged in data transfer communication with the gas monitoring unit and with the flow controlling means in intake passage, which controller unit is configured to control the flow control means using the data obtained from the gas monitoring unit as feedback information.

[0021] According to an embodiment of the invention the controller unit comprises a controller adaptation unit arranged in data transfer communication with the gas monitoring unit and with the flow controlling means in intake passage, and the controlled adaptation unit being configured to provide correspondence between the actuation position of the flow control means and gas composition information obtained by the gas monitoring unit, and the controlled adaptation

unit is configured to provide an adapted set values for controlling the flow controlling means.

[0022] According to an embodiment of the invention the controller unit comprises an information of a predetermined target value range of a predetermined variable of the fuel, such as its heat value or gas composition including concentration ranges of gas components, and that the controller unit comprises executable instructions to set an actuation variable of the flow controlling means in intake passage based on the data obtained from the gas monitoring unit.

[0023] According to an embodiment of the invention the controller unit comprises an information of distribution of a variable, such as temperature, in the tank and that the controller unit comprises executable instructions to set an actuation variable of the flow controlling means in intake passage based on the variable information of the tank. This way it is possible to minimize the rollover phenomenon in the tank in a controlled manner.

[0024] Method of transferring liquefied gas from a cryogenic tank comprising steps of arranging an intake passage into the tank, transferring liquefied gas from the tank into an intake passage wherein liquefied gas is transferred into the intake passage as at least two partial flows via at least two inlet openings at different locations of the intake passage in the tank, and controlling flow rate of the at least one of the partial flows by means of a flow control means in at least one of the inlet openings.

[0025] According to an embodiment of the invention the intake passage comprises a collector chamber into which the liquefied gas is transferred via the at least two inlet openings at different location from the tank and the liquefied gas is transferred from the collector chamber into an intake conduit.

[0026] According to an embodiment of the invention at least a portion of the liquefied gas transferred from the tank to the intake passage is recirculated back to the tank via at least one return conduit.

[0027] According to an embodiment of the invention the recirculated portion of the liquefied gas is recirculated to at least two different locations of the tank.

[0028] According to an embodiment of the invention the liquefied gas is transferred to a gas consumer configured to utilize the gas, such that the arrangement comprises a gas feed line extending from the intake passage to the gas consumer, wherein the liquefied gas is evaporated into gaseous form in a gas evaporator unit arranged to the gas feed line and at least one predetermined property of the gas is monitored in a gas monitoring unit arranged in the gas feed line downstream the gas evaporator unit, and the flow rate of the at least one of the partial flows is controlled by means of a flow control means in at least one of the inlet openings based on the monitored property.

[0029] According to an embodiment of the invention providing a correspondence between the actuation position of the flow control means and a variable obtained by the gas monitoring unit and providing adapted set values for the controlling the flow controlling means.

[0030] According to an embodiment of the invention a predetermined variable of the fuel, such as its heat value or gas composition including concentration ranges of gas components, is utilized to set an actuation variable of the flow controlling means in intake passage based on the data obtained from the gas monitoring unit.

[0031] The arrangement provides an option to provide multiple gas inlet openings and optionally multiple recycle discharge openings on several different height i.e. vertical locations inside tank.

[0032] According to an embodiment of the invention an information of a variable, such as temperature, in the tank is utilized to set an actuation variable of the flow controlling means in intake passage. This way it is possible to minimize the rollover phenomenon in the tank in a controlled manner.

[0033] By means of the invention is it possible control the fuel quality when the liquefied gas, such as natural gas inside storage tank is stratified where heaviest fractions are at bottom and lightest at top and thus accordingly the methane number and the heat value number vary.

[0034] The invention may also be utilized to manage the circumstances, such as rollover prevention or gas pressure, in the tank by using the aspect of recirculating portion of the liquefied gas to a desired vertical locations of the tank. By means of the invention it is generally possible to tune the composition of the liquefied gas in tank according need. The invention is applicable for use in connection with various gases, such as LNG, LPG, Ammonia and Hydrogen.

[0035] The exemplary embodiments of the invention presented in this patent application are not to be interpreted to pose limitations to the applicability of the appended claims. The verb "to comprise" is used in this patent application as an open limitation that does not exclude the existence of also unrecited features. The features recited in depending claims are mutually freely combinable unless otherwise explicitly stated. The novel features which are considered as characteristic of the invention are set forth in particular in the appended claims.

Brief Description of Drawings

[0036] In the following, the invention will be described with reference to the accompanying exemplary, schematic drawings, in which

Figure 1 illustrates an arrangement for transferring liquefied gas from a cryogenic tank according to an embodiment of the invention,

Figure 2 illustrates an arrangement for transferring liquefied gas from a cryogenic tank according to another embodiment of the invention,

Figure 3 illustrates an arrangement for transferring liquefied gas from a cryogenic tank according to still another embodiment of the invention,

Figure 4 illustrates an arrangement for transferring liquefied gas from a cryogenic tank according to still another embodiment of the invention, and

Figure 5 illustrates an arrangement for transferring liquefied gas from a cryogenic tank according to still another embodiment of the invention.

Detailed Description of Drawings

[0037] Figure 1 depicts schematically an arrangement 10 for transferring liquefied gas 12 from a cryogenic tank 11. It should be noted that the form and structure, as well as auxiliaries of the tank are very schematically described and only such features which are required to understand the invention are shown. The tank 11 is a cryogenic tank which is capable storing gas in liquefied form meaning that the temperature of the liquefied gas in that may be in a magnitude of minus 160 Celsius degrees or even less. More specifically the figure 1 discloses an arrangement for transferring gas to a gas consumer 14, such an internal combustion piston engine, a fuel cell or alike, which uses the gas when running. The gas consumer 14 is connected with the tank 11 by a gas feed line 20.

[0038] According to the invention the arrangement for transferring liquefied gas from a cryogenic tank is arranged to communicate with a tank space of the tank 11. There is gaseous gas forming an ullage space 13 and liquefied gas 12 in the tank 11. The arrangement of transferring liquefied gas comprises an intake passage 16 which extends into the tank 11 through the top wall 11' which borders an ullage space 13 of the tank 11. The intake passage 16 extends from the top wall 11' of the tank to inside the tank, below liquefied gas surface when the tank contains liquefied gas. In practise the intake passage 16 extends from the top of the tank to the bottom area of the tank. The arrangement comprises a pump 18 or a like which is arranged in connection with the intake passage 16. The pump is needed for sucking the liquefied gas from the tank and raising the pressure of the liquefied gas, since the pressure in the tank 11 is not high enough to transfer the gas to the consumer 14 in the embodiment of figure 1. However, the pump is not an essential feature of invention in case the tank is a pressure vessel and thus can be pressurized by e.g. a pressure build up system for maintaining adequate pressure in the tank. The pump also may be an integral part of the intake passage 16. However, in the embodiment of the figure 1 the pump 18 is arranged inside the tank 11 to the inlet end of the intake passage 16 in the gas feed line 20. By means of the pump 18 liquefied gas can be transferred from the cryogenic tank 11 into the intake passage 16 when the pump is operated. The pump is provided with a motor 18' which is advantageously outside the tank 11 and is in

force transmission connection with the pump 18, e.g. by means of a drive shaft. When the motor 18' is outside the tank the heat generated by the motor 18' when running is not transferred to the liquefied gas. The pump 18 in the figure 1 comprises three stages, having impellers and their volute housing separate to the motor 18'. It should be noted that contrary to the figure 1 arranging the motor 18' inside the tank to immediate proximity to the pump 18 is, though, a technically feasible alternative, as is depicted in the figure 2.

[0039] The liquefied gas in the tank 11 may be for example liquefied natural gas LNG which is comprised of mainly methane but also small portions of other substances. During the liquefied gas fuel is stored in the tank 11 stratification of liquid portion will take place and the quality of the gas varies at different vertical levels forming layers liquefied gas. For example due to natural boil off phenomenon, which is known as such to a skilled person in the art, the lighter components i.e. hydrocarbons with shorter chains, are evaporated more easily and therefore the surface layer L2 may contain more longer hydrocarbon chains than just below the surface. Evaporation also cools down the top surface and the liquefied gas becomes denser. Stratification of the liquefied gas is also caused by temperature and/or density differences of liquid.

[0040] As is shown in the figure 1 the intake passage 16 is provided with inlet openings 22 which are arranged at different vertical locations L1 to LN of the intake passage 16. The number and mutual vertical distances of openings may vary depending on the practical case. In order to provide a desired effect of the invention at least one of the inlet openings 22 is provided with a flow control means 24 configured to adjust the flow resistance of the opening. This means in practise that it is not necessary in all cases to either totally open or close an opening 22 but it may be enough to merely adjust the control means to more or less flow restricting position between 0 - 100 % open position i.e. changing the flow resistance of the opening. This makes it possible to control the contents of the liquefied gas which is transferred from the tank 11 to the intake passage 16 and further to the gas consumer. It is also possible to control the composition of the liquefied gas in the tank 11, and by that means prevent, or cause if so desired, the rollover phenomena to take place in the tank. As an example, in the figure 1 the inlet openings at the vertical levels L2 and LN are open, which is shown by

the arrows in the figure. Therefore the liquefied gas discharged from the tank 11 is a mixture of gas compositions at those layers. Even if not shown in the figures, an inlet opening 22 at one or each vertical location, i.e. height, may be provided with an inlet system comprising multiple inlet openings at substantially same horizontal level so that the liquefied gas may be taken out from the tank more evenly.

[0041] The arrangement can be used for practising a method of transferring liquefied gas from a cryogenic tank such that the intake passage is arranged into the tank 11 and liquefied gas is transferred from the tank into an intake passage 16 as at least two partial flows via at least two inlet openings 22 at different locations of the intake passage 16 in the tank. The flow rate of the at least one of the partial flows is controlled or adjusted by means of a flow control means 22 in at least one of the inlet openings.

[0042] An example of suitable control means is a valve, which can be of various type and it may also include an integrated electronic or digital control unit. In the figure 1 the intake passage 16 is provided with more than two inlet openings arranged at different vertical locations at the height of the passage 16, and each one of the openings is provided with a flow control means 24 configured to adjust the flow resistance of the opening. Instead of a valve the control means may be an adjustable flap, baffle, grid, vane or alike. In each of the figures height means the dimension or vertical location in the direction of liquefied gas normal in the tank. The direction of liquefied gas normal in the tank is also referred to as being vertical direction.

[0043] By means of the invention it is possible to select a suitable vertical layer, or layers, from which the fuel is discharged so that the fuel quality is as suitable as possible for a gas consumer 14, e.g. a gas engine or a fuel cell or a hybrid power system.

[0044] According to an embodiment of the invention which is shown in the figure 1 the intake passage 16 comprises a vertical collector chamber 26 which is provided with the inlet openings 22 at its wall 28 bordering the collector chamber 26 and the tank space. The openings are arranged at different vertical locations along the height of the collector chamber 26. As can be seen in the figure 1 the chamber does not necessarily extend over whole height of the tank, but it only

needs to have a height which extends through at least two layers of the stratified liquefied gas. The height can be selected suitably case by case. According to the embodiment of figure 1 the intake passage 16 comprises also an intake conduit 30 which is configured to open inside the collector chamber 26 through in opening 32 at the lower end of the conduit 30. This way the liquefied gas is transferred via the at least two inlet openings 22 at different location from the tank 11 into the collector chamber 26. The liquefied gas is transferred further from the collector chamber 16 into the intake conduit 30. The intake conduit 30 is provided with the pump 18.

[0045] Advantageously the collector chamber 26 comprises a duct, which is here referred to by the same reference 28 as the wall, previously. The intake conduit 30 is arranged to extend parallel to the duct 28 from a first end of the duct to the second end of the duct and the intake conduit is provided with an inlet 32 at its second end. It would be a feasible solution to arrange the intake conduit outside the duct 28 and lead the inlet 32 inside the duct, but advantageously the intake conduit 30 is arranged inside the duct, which is of circular cross section, and the collector chamber 26 is arranged to an annular space between the intake conduit 30 and the duct 28, since they are coaxially arranged in the figure 1.

[0046] According to an aspect of the invention the arrangement 10 is in flow communication with the gas consumer 14 configured to utilize, or for example and more specifically combust the gas, such that the gas feed line 20 is extending from the intake passage 16 to the gas consumer 14. The arrangement further comprises a gas evaporator unit 34 in the gas feed line for evaporating the liquefied gas into gaseous form and a gas monitoring unit 36 in the gas feed line downstream the gas evaporator unit. The gas evaporator unit 34 comprises one or more heat exchangers in which heat is brought to the liquefied gas so as to evaporate it into gaseous form and increase its temperature to suitable level.

[0047] The gas monitoring unit comprises sensors by means of which at least one predetermined property of the gas, or desired physical properties of the gas are monitored substantially constantly. According to an embodiment of the invention the composition of the gas is monitored. Based on the constituents of the gas obtained by using the gas monitoring unit it is possible to define the heat

value of the gas, which in turn effects on the performance of the gas consumer 14.

[0048] The arrangement comprises also a controller unit 38 arranged in data transfer communication with the gas monitoring unit and with the flow controlling means in intake passage, which controller unit 38 is configured to control the flow control means using the data obtained from the gas monitoring unit as feedback information. According to an embodiment of the invention the controller unit 38 comprises a controller adaptation unit 40, which can be so called a machine learning unit arranged in data transfer communication with the gas monitoring unit 36 and with the flow controlling means 22 in intake passage 16.The controller adaptation unit 40 is configured to provide correspondence between actuated mutual positions of the flow control means 22 and the gas composition obtained by the gas monitoring unit, and the controller adaptation unit 40 is configured to provide adapted set values for controlling the flow controlling means. Thus, the flow rate of the at least one of the partial flows is controlled by means of a flow control means 20 in at least one of the inlet openings based on the monitored gas property. This way by providing a correspondence between the actuation position of the flow control means and a variable obtained by the gas monitoring unit adapted set values for the controlling the flow controlling means is provided.

[0049] The controller unit 38 comprises an information of a predetermined target value range of a predetermined variable of the fuel, such as its heat value or gas composition including concentration ranges of gas components, and the controller unit 38 comprises executable instructions to set an actuation variable of each one of the flow controlling means in intake passage based on the data obtained from the gas monitoring unit.

[0050] A predetermined variable of the fuel, such as its heat value or gas composition including concentration ranges of gas components, is utilized to set an actuation variable of the flow controlling means in in-take passage based on the data obtained from the gas monitoring unit.

[0051] Figure 2 shows an embodiment of the invention which is based on the embodiment of the figure 1 but where some of the part of the arrangement differs from those in the figure 1. Firstly, the intake passage 16 differs of its structure

from that shown in the figure 1. As is shown in the figure 2 the intake passage 16 comprises a vertical collector chamber 26 which is arranged to extend from the top of the tank 11 to above its bottom. In other words the intake conduit does not extend over full height of the tank space. Secondly, in the embodiment of the figure 2 the pump 18 is located near the bottom part of the collector chamber 26 and the pump 18 has integrated motor 18'.

[0052] The arrangement shown in the figure 2 can be used for practising a method of transferring liquefied gas from a cryogenic tank such that the intake passage is arranged into the tank 11 and liquefied gas is transferred from the tank into an intake passage 16 as at least two partial flows via at least two inlet openings 22 at different locations of the intake passage 16 in the tank. The flow rate of the at least one of the partial flows is controlled or adjusted by means of a flow control means 24 in at least one of the inlet openings.

[0053] Figure 3 shows schematically the arrangement for transferring liquefied gas from a cryogenic tank according to an embodiment of the invention. The arrangement comprises an intake passage 16 extending into the tank 11, which passage 16 comprises at least two parallel intake conduits 30'' each provided with a flow control means 24 and a pump 18. The conduits 30'' of the passage 16 are provided with inlet openings 22 arranged at different vertical locations of the passage 16. The intake conduits 30'' are all connected together at the outlet side of the pumps 18 such that liquefied gas can be transferred from the cryogenic tank into the intake passage when the respective pump is operated from desired level of the tank 11. Control of intake of the liquefied gas may be performed by controlling the flow control means 24 and/or the pumps 18.

[0054] The arrangement shown in the figure 3 can be used for practising a method of transferring liquefied gas from a cryogenic tank such liquefied gas is transferred from the tank 11 into an intake passage 16 as at least two partial flows via at least two inlet openings 22 at different locations of the intake passage 16 in the tank. The flow rate of the at least one of the partial flows is controlled or adjusted by means of a flow control means 24 in at least one of the inlet openings.

[0055] Further the arrangement shown in the figure 3 is in flow communication with a gas consumer 14 configured to utilize the gas, such that the arrangement comprises a gas feed line 20 extending from the intake passage 16 to the gas consumer 14. The arrangement further comprising a gas evaporator unit 34 in the gas feed line for evaporating the liquefied gas into gaseous form and a gas monitoring unit 36 in the gas feed line downstream the gas evaporator unit, and a controller unit 38 arranged in data transfer communication with the gas monitoring unit and with the flow controlling means in intake passage, which controller unit 38 is configured to control the flow control means 24 using the data obtained from the gas monitoring unit as feedback information.

[0056] The arrangement shown in the figure 3 can be used for practising a further method of transferring liquefied gas from a cryogenic tank to a gas consumer 14 configured to utilize the gas, wherein the liquefied gas is evaporated into gaseous form in a gas evaporator unit arranged to the gas feed line and at least one predetermined property of the gas is monitored in a gas monitoring unit 36 arranged in the gas feed line downstream the gas evaporator unit, and the flow rate of the partial flow in each one of the conduit 30'' is controlled by means of a flow control means in at least one of the inlet openings based on the monitored property.

[0057] The gas monitoring unit 36 may be configured to monitor either gaseous or liquefied gas and therefore its location may be either upstream or downstream the gas evaporator unit 34.

[0058] Figure 4 shows a further embodiment of the invention which in addition the arrangement is capable of controlling the quality of the gas transferred from the cryogenic tank to the gas consumer 14, has a feature for controlling the stratification of the liquefied gas in the tank 11. As it becomes clear from the figure 4 it has corresponding elements to the figure 3 and operates in the same way, notwithstanding the feature for controlling the stratification of the liquefied gas in the tank 11 and having a shared pump 18 outside the tank 11. The intake conduits 30'' are all connected together at the inlet side of the pump 18 such that liquefied gas can be transferred from the cryogenic tank into the intake passage when the pump is operated. The arrangement comprises at least one return conduit 21 which extends from the gas feed line 20 into the tank 11. Each one of the

inlet openings 22 may be provided with a one-way valve. This way the passage 16 remains filled with liquefied gas during down times of the pump ensuring the operation of the pump when started. It is also possible to control the pressure in the tank such that it is slightly higher than in the gas feed line 20 at the start. This ensures that the pumps inlet side is filled with liquefied gas.

[0059] In the figure 4 there are four return conduits 21 which are arranged such that the liquefied gas containing the mixture or composition in the intake passage 16 can be returned back to one or several selected vertical levels in the tank 11. This way, at least a portion of the liquefied gas transferred from the tank to the intake passage is recirculated externally (to the tank 11) back to the tank via at least one return conduit. The arrangement of the figure 4 comprises three return conduits. The conduits extend from the pressure side or downstream side in the flow direction of the gas to the tank 11. Each return conduit 21 is provided with a valve 25 to control the flow through the conduit 21. A return duct may be provided with a distribution system comprising multiple outlets at substantially same horizontal level so that the returned gas may be delivered back to the tank more evenly. It should be understood that a system of return conduits may be applied in anyone of the embodiments disclosed. In the embodiment of the figure 1 it can be integrated to the duct 28. Each one of the inlet openings 22 may be provided with a one-way valve. This way the passage 16 remains filled with liquefied gas during down times of the pump.

[0060] Figure 5 shows a further embodiment of the invention which in addition to the arrangement is capable of controlling the quality of the gas transferred from the cryogenic tank to the gas consumer 14 by selecting a predetermined level of tank from which the gas is removed, it has a feature for controlling the stratification of the liquefied gas in the tank 11. As it becomes clear from the figure 5 it has corresponding elements to the figure 1 and operates in the same way, notwithstanding the feature for controlling the stratification of the liquefied gas in the tank 11. The arrangement comprises at least one return conduit 21 inside the tank 11 which extends from the intake passage 16 into the tank 11 through the duct 28. In other words the return conduits branch from the intake passage 16 inside the tank 11, at pressure side of the pump 18. In the figure 5 there are three return conduits 21 which are arranged such that the liquefied gas

containing the mixture or composition in the intake passage 16 can be returned back to one or several selected vertical levels in the tank 11. The number and vertical location of the return conduits 21 can be selected as desired case by case. This way, at least a portion of the liquefied gas removed from the tank to the intake passage 16 is recirculated back internally to the tank via at least one return conduit 21. This minimizes warming up of the recirculated gas. The arrangement of the figure 5 comprises three return conduits. Each return conduit 21 is provided with a valve 25 to control the flow through the conduit 21. In addition to what is disclosed with reference to the figure 1 in the embodiment of the figure 5 the controller unit 38 is arranged in data transfer communication with the gas monitoring unit and with the valves 25. The controller unit 38 is configured to control the valves 25 using the data obtained from the gas monitoring unit as feedback information. The conduits extend from the pressure side, or downstream side of the pump 18 in the flow direction of the gas, to the tank 11. The conduits are integrated to the duct 28. It is possible that in some cases the internal recirculation as is shown in the figure 5 and the external recirculation shown in the figure 4 are combined in connection with one tank.

[0061] While the invention has been described herein by way of examples in connection with what are, at present, considered to be the most preferred embodiments, it is to be understood that the invention is not limited to the disclosed embodiments, but is intended to cover various combinations or modifications of its features, and several other applications included within the scope of the invention, as defined in the appended claims. The details mentioned in connection with any embodiment above may be used in connection with another embodiment when such combination is technically feasible.

Claims

1. An arrangement for transferring liquefied gas from a cryogenic tank (11) comprising
an intake passage (16) extending into the tank (11),
a pump (18) arranged in connection with the intake passage (16) such that liquefied gas can be transferred from the cryogenic tank (11) into the intake passage (16) when the pump (18) is operated,
characterized in that
the intake passage (16) is provided with at least two inlet openings (22) arranged at different locations (L1…LN) of the intake passage (16),
at least one of the inlet openings (22) is provided with a flow control means (24) configured to adjust the flow resistance of the inlet opening (22).

2. The arrangement for transferring liquefied gas from a cryogenic tank (11) according to claim 1, **characterized** in that intake passage (16) comprises a vertical collector chamber (26) and an intake conduit (30), wherein the intake conduit (30) is configured to open inside the collector chamber (26) and the collector chamber (26) is provided with said at least two inlet openings (22) arranged at different locations at the height of the collector chamber (26).

3. The arrangement for transferring liquefied gas from a cryogenic tank (11) according to claim 2, **characterized** in that the collector chamber (26) comprises a duct (28) and the intake conduit (30) is arranged to extend parallel to the duct (28) from a first end of the duct (28) to the second end of the duct (28) and that the intake conduit (30) is provided with an inlet through which the intake conduit (30) opens inside the duct (28) at its second end.

4. The arrangement for transferring liquefied gas from a cryogenic tank (11) according to claim 3, **characterized** in that the intake conduit (30) is inside the duct (28), wherein the collector chamber (26) is arranged to an annular space between the intake conduit (30) and the duct (28).

5. The arrangement for transferring liquefied gas from a cryogenic tank (11) according to claim 1, **characterized** in that the intake passage (16) is provided with more than two inlet openings (22) arranged at different locations at the height of the passage, and each one of the openings is provided with a flow control means (24) configured to adjust the flow resistance of the opening.

6. The arrangement for transferring liquefied gas from a cryogenic tank (11) according to claim 1, **characterized** in that the intake passage (16) is arranged to a cryogenic tank (11) such that is extends from a top wall (11') of the tank (11) to inside the tank (11) in a below liquefied gas surface when the tank (11) containing liquefied gas.

7. The arrangement for transferring liquefied gas from a cryogenic tank (11) according to claim 1, **characterized** in that the arrangement comprises at least one return conduit (21) arranged such that the liquefied gas containing the mixture or composition in the intake passage (16) can be returned back to the tank (11).

8. The arrangement for transferring liquefied gas from a cryogenic tank (11) according to claim 7, **characterized** in that the arrangement comprises at least two return conduits (21) which into the tank (11) at different vertical locations thereof.

9. The arrangement for transferring liquefied gas from a cryogenic tank (11) according to anyone of the preceding claims, **characterized** in that the arrangement is in flow communication with a gas consumer (14) configured to utilize the gas, such that the arrangement comprises a gas feed line (20) extending from the intake passage (16) to the gas consumer (14), wherein the arrangement further comprising a gas evaporator unit (34) in the gas feed line (20) for evaporating the liquefied gas into gaseous form and a gas monitoring unit (36) in the gas feed line (20) downstream the gas evaporator unit (34), and a controller unit (38) arranged in data transfer communication with the gas monitoring unit (36) and with the flow controlling means in intake passage (16), which controller unit (38) is configured to control the flow control means (24) using the data obtained from the gas monitoring unit (36) as feedback information.

10. The arrangement for transferring liquefied gas from a cryogenic tank (11) according to claim 9, **characterized** in that the controller unit (38) comprises a controller adaptation unit (40) arranged in data transfer communication with the gas monitoring unit (36) and with the flow controlling means in intake passage (16), and the controlled adaptation unit (40) being configured to provide correspondence between the actuation position of the flow control means (24) and gas composition information obtained by the gas monitoring unit (36), and the controlled adaptation unit is configured to provide an adapted set values for controlling the flow controlling means (24).

11. The arrangement for transferring liquefied gas from a cryogenic tank (11) according to claim 9, **characterized** in that the controller unit (38) comprises an information of a predetermined target value range of a predetermined variable of the fuel, such as its heat value or gas composition including concentration ranges of gas components, and that the controller unit (38) comprises executable instructions to set an actuation variable of the flow controlling means in intake passage (16) based on the data obtained from the gas monitoring unit (36).

12. Method of transferring liquefied gas from a cryogenic tank (11) comprising steps of arranging an intake passage (16) into the tank (11), transferring liquefied gas from the tank (11) into an intake passage (16) wherein liquefied gas is transferred into the intake passage (16) as at least two partial flows via at least two inlet openings (22) at different locations of the intake passage (16) in the tank (11), and controlling flow rate of the at least one of the partial flows by means of a flow control means (24) in at least one of the inlet openings (22).

13. Method of transferring liquefied gas from a cryogenic tank (11) according to claim 12, **characterized** in that the intake passage (16) comprises a collector chamber (26) into which the liquefied gas is transferred via the at least two inlet openings (22) at different location from the tank (11) and the liquefied gas is transferred from the collector chamber (26) into an intake conduit (30).

14. Method of transferring liquefied gas from a cryogenic tank (11) according to claim 12, **characterized** in that at least a portion of the liquefied gas transferred from the tank (11) to the intake passage (16) is recirculated back to the tank (11) via at least one return conduit.

15. Method of transferring liquefied gas from a cryogenic tank (11) according to claim 14, **characterized** in that the recirculated portion of the liquefied gas is recirculated to at least two different locations of the tank (11).

16. Method of transferring liquefied gas from a cryogenic tank (11) according to claim 12, **characterized** in that the liquefied gas is transferred to a gas consumer (14) configured to utilize the gas, such that the arrangement comprises a gas feed line (20) extending from the intake passage (16) to the gas consumer (14), wherein the liquefied gas is evaporated into gaseous form in a gas evaporator unit (34) arranged to the gas feed line (20) and at least one predetermined property of the gas is monitored in a gas monitoring unit (36) arranged in the gas feed line (20) downstream the gas evaporator unit (34), and the flow rate of the at least one of the partial flows is controlled by means of a flow control means (24) in at least one of the inlet openings (22) based on the monitored property.

17. Method of transferring liquefied gas from a cryogenic tank (11) according to claim 12, **characterized** by providing a correspondence between the actuation position of the flow control means (24) and a variable obtained by the gas monitoring unit (36) and providing adapted set values for the controlling the flow controlling means.

18. Method of transferring liquefied gas from a cryogenic tank (11) according to claim 12, **characterized** in that a predetermined variable of the fuel, such as its heat value or gas composition including concentration ranges of gas components, is utilized to set an actuation variable of the flow controlling means in intake passage (16) based on the data obtained from the gas monitoring unit (36).

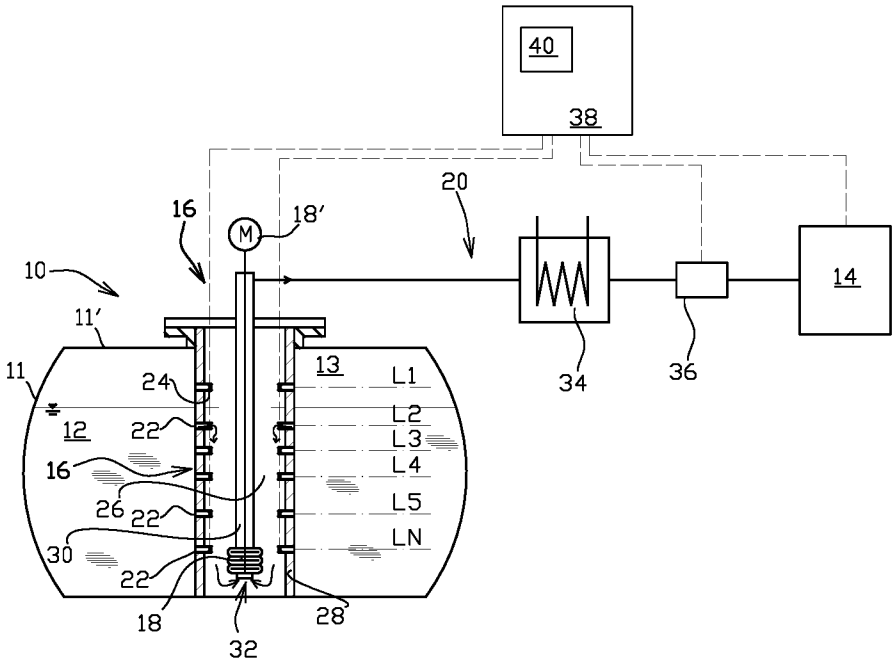
40
38
20
16
18'
M
10
11'
11
13
L1
24
12
22
L2
L3
16
L4
26
22
L5
LN
30
22
18
32
28
34
36
14

FIG. 1

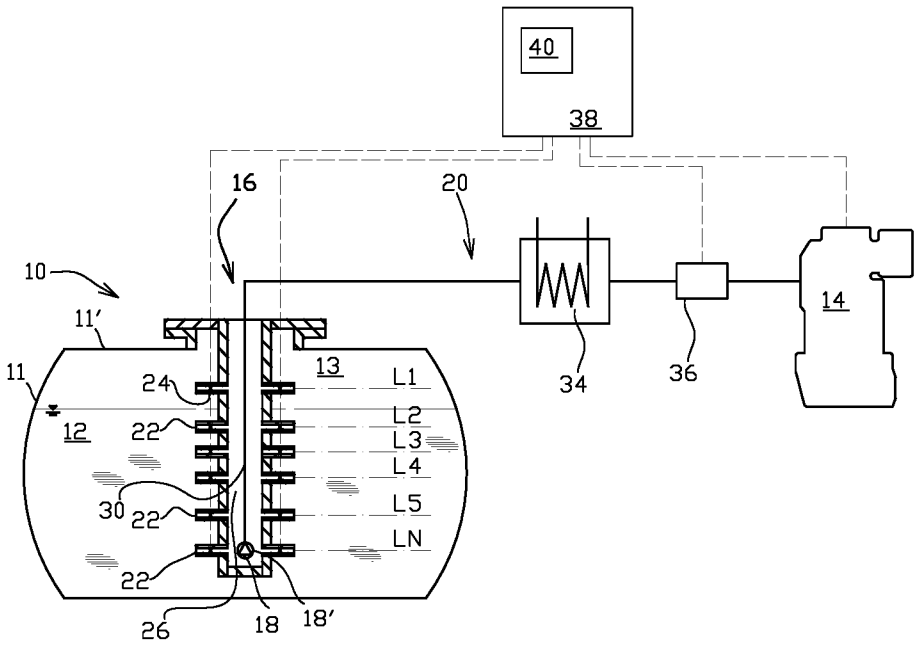
40
38
16
20
10
11'
11
12
24
22
30
22
22
26
18
18'
13
L1
L2
L3
L4
L5
LN
34
36
14

FIG. 2

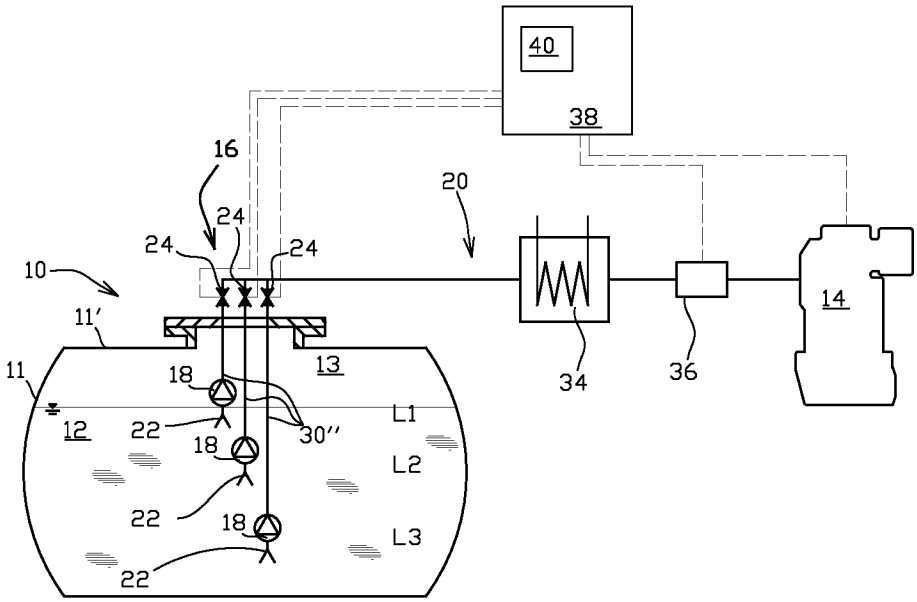
40
38
16
20
24
24
24
10
11'
11
13
18
12
22
18
30''
L1
L2
22
18
L3
22
34
36
14

FIG. 3

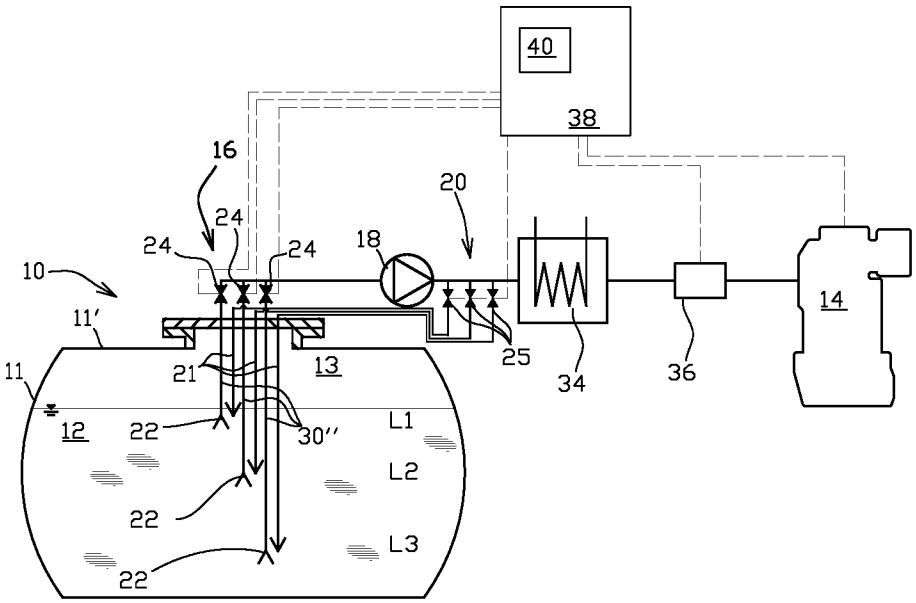
40
38
16
20
24
24
24
18
10
11'
11
21
13
25
34
36
14
12
22
30''
L1
L2
22
L3
22

FIG. 4

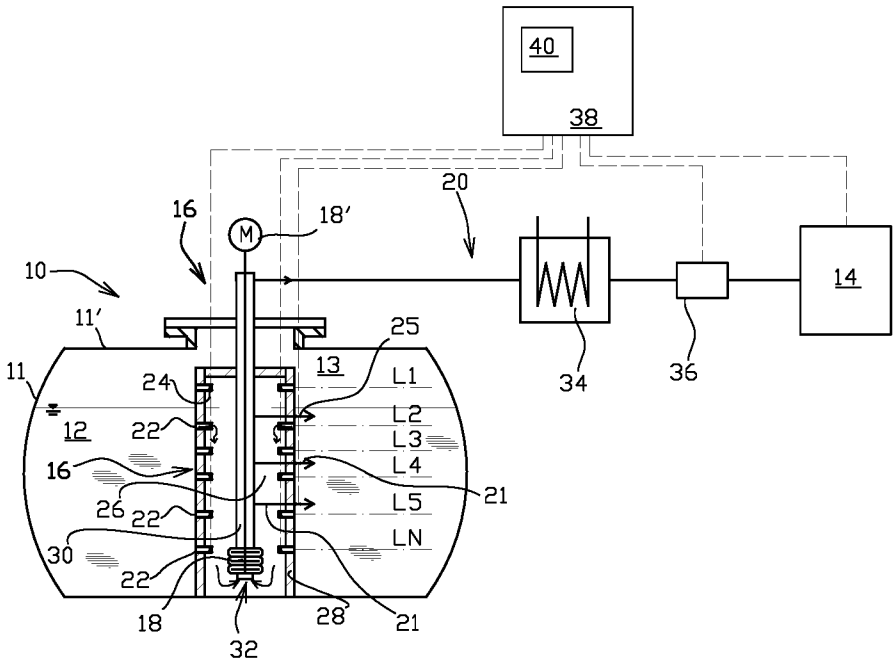
40
38
20
16
18'
M
10
14
11'
25
11
13
L1
24
L2
12
22
L3
16
L4
21
26
22
L5
LN
30
22
18
28
21
32
34
36

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/056115

A. CLASSIFICATION OF SUBJECT MATTER
INV. F17C1/00
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 2015/078106 A1 (CHINA NAT OFFSHORE OIL CORP [CN]; OFFSHORE OIL ENG CO LTD [CN] ET AL.) 4 June 2015 (2015-06-04)	1,5-12, 14-18
A	figure 2 paragraph [0010]	2-4,13

A	EP 2 032 428 A1 (WAERTSILAE FINLAND OY [FI]) 11 March 2009 (2009-03-11) cited in the application the whole document	1-18

A	US 2007/068176 A1 (POZIVIL JOSEF [FR]) 29 March 2007 (2007-03-29) the whole document	1-18

A	JP S57 9396 A (TOKYO ELECTRIC POWER CO; NIPPON KOKAN KK) 18 January 1982 (1982-01-18) the whole document	1-18

☐ 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	Date of mailing of the international search report
20 December 2019	14/01/2020

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

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2019/056115

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2015078106 A1	04-06-2015	CN 103644454 A	19-03-2014
		WO 2015078106 A1	04-06-2015
EP 2032428 A1	11-03-2009	CN 101479150 A	08-07-2009
		EP 2032428 A1	11-03-2009
		FI 20065445 A	28-12-2007
		JP 5383488 B2	08-01-2014
		JP 2009541140 A	26-11-2009
		KR 20090021179 A	27-02-2009
		NO 337470 B1	18-04-2016
		US 2009239426 A1	24-09-2009
		WO 2008000898 A1	03-01-2008
US 2007068176 A1	29-03-2007	AT 519064 T	15-08-2011
		CN 1871474 A	29-11-2006
		CN 103090180 A	08-05-2013
		EP 1660806 A1	31-05-2006
		JP 4796491 B2	19-10-2011
		JP 2007504414 A	01-03-2007
		KR 20070019636 A	15-02-2007
		PL 1660806 T3	30-12-2011
		US 2007068176 A1	29-03-2007
		WO 2005022027 A1	10-03-2005
JP S579396 A	18-01-1982	NONE	