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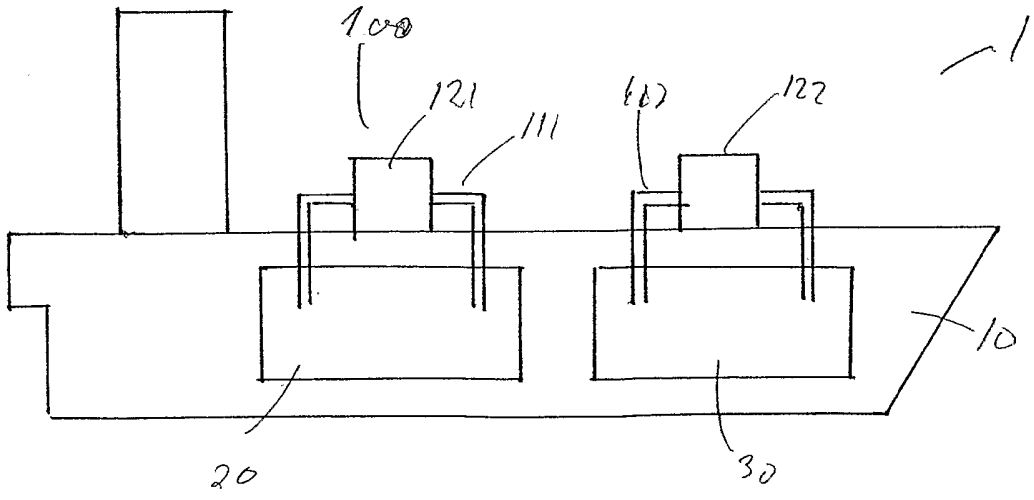
(54) **Title:** EQUIPMENT FOR A TANKER VESSEL CARRYING A LIQUEFIED HYDROCARBON OR LIKE PRODUCT



(57) **Abstract:** The present invention relates to tanker vessels carrying hydrocarbon products such as Liquefied Petrol Gas, LPG, and where said tanker vessels are equipped with one or more of the following equipment: A cooling system comprising a compressor section for producing a cooling fluid in the form of a condensate of the cargo product, a housing for said compressors, means for collecting residual gas from the tanks of the vessel, equipment for disposing of said residual gas and means for tempering the hydrocarbon contained in the tanks.

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EQUIPMENT FOR A TANKER VESSEL CARRYING A LIQUEFIED HYDROCARBON OR LIKE PRODUCT

FIELD OF THE INVENTION

The present invention relates to ships, more specifically tanker vessels (carriers) carrying hydrocarbon products such as Liquefied Petroleum Gas, LPG, or a gas having similar physical properties, e.g. a low boiling point, etc. such as Vinyl Chloride Monomer (VCM) or Ammonium (NH_3); and where said tanker vessels are equipped with one or more of the following equipment: A cooling system comprising a compressor section for producing a cooling fluid in the form of a condensate of the cargo product, a housing for said compressors, means for collecting residual gas from the tanks of the vessel, equipment for disposing of said residual gas and means for tempering the hydrocarbon contained in the tanks.

BACKGROUND AND SUMMARY OF THE INVENTION

Tanker vessels (hereinafter referred to as LPG carriers) carrying LPG or other liquefied hydrocarbon products or a gas having similar physical properties, such as Vinyl Chloride Monomers or Ammonium (NH_3) need a cooling system for maintaining the hydrocarbon product in liquid form. LPG carriers for these purposes belong to the so-called "semi-ref" type or the "fully-ref" type, where the term "ref" refers to the refrigeration need of the cargo and the specialized equipment of the ship for the purpose of cooling the hydrocarbon cargo. In the semi-ref type the cargo is pressurized and refrigerated. LPG carriers of the fully-ref type are often very large ships, where the cargo is only refrigerated, not pressurized. There also exists another type of typically small or medium sized LPG carriers, the pressurized type, where the cargo is fully pressurized. The boiling point of such liquefied hydrocarbon products is about $-100^{\circ}C$, depending on the pressure and the nature of the hydrocarbon product carried in the tanks of a LPG carrier. As a consequence thereof, a LPG carrier is equipped with a number of cargo tanks forming a basic part of the vessel, and besides the tanks, several service equipments are provided. For the purpose of cooling the LPG cargo, one part of the service equipment constitutes a compressor section for liquefying a cooling medium for the cooling system adapted for cooling the hydrocarbon cargo carried in the tanks of the vessel. Typically the cooling medium is the LPG product itself, i.e. a condensate of the cargo product. According to known LPG carrier designs, in order to reduce the costs of production of the LPG carrier, one compressor section of the cooling system is installed in one housing and is intended for cooling all of the tanks of the vessel. The compressor section often comprises a plurality of compressors. LPG carriers are typically small to medium sized ships comprising 2-4 cargo tanks disposed within the

hull of the vessel. The above mentioned compressor section is fixedly installed on the upper, open deck of the vessel. In order to transport the LPG cargo between the cargo tanks and the compressor section, where the hydrocarbons are refrigerated before being returned to the cargo tanks, a comprehensive network of piping to and from the cargo tanks and the individual compressors of the compressor section is also arranged on the upper, open deck of the vessel. Such a network is a very complicated structure often referred to as a "cage".

This layout of the cooling system has certain advantages in that the central compressor section is cost efficient from the point of view that compressors are costly, and the number therefore needs to be minimized. However, there are also a number of disadvantages of such a prior art cooling system. As a consequence of the cooling system layout the liquid cargo must travel a long way from the cargo tanks to the compressor section resulting in large loss of energy for the cooling process (an influx of heat to the cooling medium in the piping system increases the need for cooling, causing an increase in the energy needed for the cooling process). The more tanks provided on the carrier, the longer the piping system. This means that the compressor capacity needs to be increased. Further, in order to reduce the energy loss in the piping system, the piping system may require an additional space consuming insulation.

It is an object of a first aspect of the present invention to provide an improved, flexible and/or more energy efficient cooling system for a tanker vessel.

According to a first aspect of the invention, the LPG carrier comprises a cooling system for cooling hydrocarbon products in the cargo-tanks of the vessel, and where at least one first housing is provided containing a first compressor section for the cooling system, and where at least one second housing is provided containing a second compressor section for the cooling system, said at least first compressor section being connected by piping to a first part of a cooling system for cooling the hydrocarbon product in tanks of the vessel, and said second compressor section being connected by piping to a second part of the cooling system for cooling the hydrocarbon product in tanks of the vessel, said first part of the cooling system being provided nearer, viewed along the piping, to the first compressor section than to the second compressor section, and said second part of the cooling system being provided nearer, viewed along the piping, to the second compressor section than to the first compressor section, said first part comprising at a cargo tank or a set of cargo tanks, and said second part comprising another cargo tank or another set of cargo tanks.

Providing the compressor section of the cooling system in at least two individual housings would not from the common knowledge in LPG carrier design be considered a very well

suited solution, because the manufacturing costs of the vessel will be increased as a consequence, especially due to the number of compressor sections having to be multiplied with the number of cargo tanks provided in the hull of vessel. Nevertheless, the invention do benefit to the reducing of costs, when taking into account the overall costs of both manufacturing and operating the vessel. The advantages comprise reduction of the entire length of pipes of the cooling system, and comprise a subsequent reduction of temperature loss along the pipes, between the compressor section and the tanks.

Fig. 1 shows, in a schematic form a section through a prior art LPG carrier;

Fig.2 shows, in a schematic form a section through a LPG carrier according to a first aspect of the invention.

In Fig. 1 a prior art LPG carrier 1 having a hull 10 is shown. Within said hull 10 a plurality of hull cargo tanks 20, 30 are provided. A cooling system 100 is provided in said carrier 1, comprising said tanks 20, 30, a piping system or network 110 and a compressor section 120. The piping system or network 110 provides a connection between the compressor section 120 and the respective tanks 20, 30, such that the LPG content of the tanks can be passed from either of the tanks 20, 30 through the compressor section 120, where it is cooled and passed back to either of the tanks 20, 30.

In Fig. 2 a LPG carrier 1 is shown. The carrier has a hull 10. Within said hull 10 a plurality of hull cargo tanks 20, 30 are provided. In the figure two are shown. A cooling system 100 is provided in said carrier 1, comprising said tanks 20, 30, at least one piping system or network 111, 112 for each cargo tank 20, 30, and two compressor sections 121, 122 . The piping system or network 111, 112 provides a connection between each compressor section 121,122 and the respective tanks 20, 30, such that the LPG content of the tanks can be passed from a tanks 20, 30 through a compressor section 121, 122, respectively, where it is cooled and passed back to the tanks 20, 30. The compressor sections 121, 122 are provided in respective housings on the upper, open deck of the vessel 1.

The carrier 1 is shown having two tanks 20, 30. However, the invention according to this first aspect of the invention would apply to ships having a larger number of tanks. Preferably, a compressor section is provided for each cargo tank. However, in an embodiment of this aspect of the invention individual sections could be assigned to a set, e.g. pairs, of tanks.

The piping systems 111, 112 may be cross-linked (not shown) such that the first compressor section 121 is also connected to tank 30 and the second compressor section

122 is also connected to tank 20. Thus, if one compressor sections sets out or for e.g. repair reasons is set out, the cooling system may provide a flexible and additional backup/safety opportunity.

Between payloads of different types of LPG products, LPG carrier cargo tanks need to be purged in order not to contaminate one hydrocarbon product with another. In the field of tanker vessels, purging is the process of cleaning one or more tanks of the vessel of any hydrocarbon product in the tanks of the vessel in order to enable the vessel to carry different hydrocarbon products at different intervals during operation of the vessel.

Typically, an inert gas is used to purge the cargo tanks of the vessel. In the present context an inert gas is a gas, which is inert with respect to the hydrocarbons transported in the vessel tanks, and/or in particular to oxygen, O_2. It is vital that the oxygen level is kept as far below the 12% explosion danger limit as possible, and never higher than a safety margin set at 1/3 of the latter, i.e. at 4%. Such an inert gas may be Nitrogen (N_2) or washed exhaust gas from combustion engines. Usually LPG carriers purge their tanks at land based purging stations situated at certain ports.

During purging of one or more of the tanks of the vessel, according to known LPG carrier designs, any residual gas is ventilated to the ambient atmosphere, and because of the hydrocarbon being volatile in the ambient atmosphere, this has until now been considered a ready and easy way of disposing the residual hydrocarbon product. However, due to the increasing environmental awareness this disposal is not desirable.

According to a second aspect of the invention, the invention comprises a gas containment system for collecting and containing any residual gas of the hydrocarbon product from one or more tanks of the vessel, subsequent to the main part of hydrocarbon product having been discharged.

According to the contemporary modus operandi of LPG carriers, a gas containment system is not at all necessary for a LPG carrier carrying liquefied hydrocarbon products. Therefore, providing a gas containment system is a measure, which is not at all expected in relation to operating such a vessel. Nevertheless, advantages do occur in collecting and containing the residual gas of the hydrocarbon product of the vessel.

The advantages relate to different aspects such as disposing of the residual gas, complete purging and completely inerting the tanks of the vessel already before docking, and still other advantages remain. The advantages may in themselves or in combination reduce the overall cost of operating the vessel, although it may result in an increase of the costs of

designing and manufacturing the vessel when providing the vessel with a gas containment system.

Preferably, the gas containment system comprises at least one individual containment tank of said gas containment system, said at least one individual containment tank being situated in at least one housing, and said at least one housing comprising at least one inlet for the gas of the hydrocarbon product being collected from one or more of the tanks of the vessel, and at least one outlet for the gas having been collected and stored in the individual containment tank.

By collecting and containing the residual gas in one or more individual containment tanks being provided in individual housings, it becomes very easy to choose any utilisation or disposing of the gas after having collected the gas. Preferably the residual gas is destructed.

The containment tank in the housing is preferably arranged on the upper, open deck of the vessel.

In a preferred embodiment of the gas containment system according to the second aspect of the invention, said at least one housing is individual to the vessel and constitutes a shipping container having dimensions according to ISO (International Standard Organization), preferably a 20 feet ISO shipping container, alternatively a 40 feet ISO shipping container, alternatively a shipping container of another ISO dimension.

The flexibility of the individual, not fixedly installed housing of the gas containment system, especially when the housing is an ISO shipping container, is advantageous and may nonetheless compensate for the disadvantage of providing a system which is not in itself necessary for operating the vessel. The at least one housing may be easily loaded and unloaded onto and off a ship or a truck.

In a possible embodiment of the gas collecting system according to the second aspect of the invention, at least two housings each comprising containment tanks are provided, one of the at least two housings intended for containing one hydrocarbon product being collected from one or some tanks of the vessel, and another of the at least two individual housings intended for containing another hydrocarbon product collected from another or other of the tanks of the vessel.

By containing one type of hydrocarbon gas in at least one individual containment tank being provided in an individual housing, and containing another type of hydrocarbon gas in

at least one other individual containment tank being provided in another individual housing, it becomes very easy to choose any utilisation of - or method of disposing of - the gas after having collected the gas. Utilisation may be chosen depending on the type of hydrocarbon gas best suited or perhaps necessary for a chosen utilisation. Different hydrocarbon gasses are readily available, thus rendering the choice of hydrocarbon gas at all possible, and the subsequent utilisation/destruction of the chosen hydrocarbon gas easy.

Also, if the vessel carries different liquefied hydrocarbon products in each cargo tank, residual gas collection may be effected for all the different hydrocarbon products without having to mix the products and without having to discharge to the ambient atmosphere, one or more products not capable of being collected if only one gas collecting tank is provided.

In a preferred embodiment of the at least two housings for containment of residual hydrocarbon products, both of said at least two housings are individual to the vessel and both of said two housings constitute a shipping container having dimensions according to ISO (International Standard Organization), preferably a 20 feet ISO shipping container, alternatively a 40 feet ISO shipping container, alternatively a shipping container of another ISO dimension.

The flexibility of at least two individual, not fixedly installed housings of the gas containment system, especially when the housings are ISO shipping containers, is advantageous and may nonetheless compensate for the disadvantage of providing a system, which is not necessary for operating the vessel. The at least two housings may be easily loaded and unloaded onto and off a ship or a truck. Also, the one housing may be loaded and unloaded onto or off a ship or a truck independently on any loading or unloading of the other housing onto or off a ship or a truck.

When collecting the residual gas, the residual gas is contained in the containment system and may subsequently be destroyed in an environmentally friendly way or be utilized for later cargo operations.

In either of the embodiments of the second aspect of the invention, the utilisation or destruction of any of the different residual hydrocarbon products need not be related to utilisation/destruction on board the vessel from which the gas is collected. The utilisation/destruction may be effected on board another vessel, or utilisation/destruction may be effected in relation to other vessels than a ship, perhaps a truck or an aeroplane, and the utilisation/destruction may also be effected at energy consuming plants on land or

in other gas utilising plants based on land. According to a third aspect of the invention, the residual gas is destroyed in the auxiliary machinery of the vessel.

In one embodiment according to the third aspect of the invention, the residual gas is destroyed in the machinery of the vessel, i.e. on board the vessel. Thus, destruction may be obtained during operation of the vessel, i.e. also when the vessel is operated at sea from one port to another port. Thereby, an environmentally advantageous disposing of the residual gas may be obtained without any hazardous consequences, while operating at sea. In a preferred embodiment of this aspect of the invention, the residual gas is fed through the air supply to the auxiliary engines (for electrical power supply) on board the vessel.

According to a fourth aspect of the invention, the invention comprises a purging system for purging and rendering inert one or more tanks of the vessel, and where at least one inert gas producing unit of said purging system is situated in at least one housing, said housing comprising at least one outlet for the inert gas being inert to any hydrocarbon product carried by the vessel, and where said housing is individual to the vessel and constitutes a shipping container having dimensions according to ISO (International Standard Organization), preferably a 20 feet ISO shipping container, alternatively a 40 feet ISO shipping container, alternatively a shipping container of another ISO dimension.

Installing the inert gas producing unit of the purging system in one or more individual housings provides flexibility such that one or more individual, not fixedly installed housings of the inert gas producing unit, may easily be brought on board a vessel where it is needed. E.g. for a fleet of ships the number of inert gas producing units may be shared. Also this provides for easy instalment on the vast number of ships that do not comprise such equipment at present. This is especially the case when the housings are ISO shipping containers. The flexibility of this equipment may compensate for the disadvantage of not always having the inert gas producing unit on board the vessel.

According to this aspect of the invention, said inert gas producing unit is preferably a Nitrogen (N_2) generator such as a Pressure Swing Adsorption plant, PSA.

A purging compressor section, separate from the above-mentioned compressor sections used for cooling the hydrocarbon product (first aspect) in one or more tanks of the vessel, is located on the vessel. This purging compressor section is used for producing dry air for the production of nitrogen gas for purging and rendering inert the one or more tanks of the vessel, thus constituting part of a purging system of the vessel. This compressor section of the purging system of a LPG carrier is in a preferred embodiment designed as stationary,

integrated part of the vessel and is installed during manufacture of the vessel. Thereby, it is assured that the compressor section of the purging system is always on board the vessel, always ready for purging and inerting of the tanks of the vessel, i.e. when a new hydrocarbon product is to be carried in one or more tanks of the vessel, or when any other hydrocarbon product is to be substituted by another hydrocarbon product. This purging compressor section is connected to at least one dry air inlet of the at least one housing for the inert gas producing unit of said purging system. In an alternative embodiment the purging compressor section of the purging system is situated inside a separate, detachable housing such as a shipping container (e.g. a 20 feet ISO shipping container, alternatively a 40 feet ISO shipping container, and the inert gas producing unit is connected thereto through at least one pipe while remaining inside the respective containers during operation. However, in yet an embodiment the purging compressor section and the inert gas producing unit may be formed in the same separate, detachable housing of the vessel, e.g. a 20 feet ISO shipping container, alternatively a 40 feet ISO shipping container.

Prior art LPG carriers comprise tempering systems using seawater for tempering the LPG cargo in the cargo tanks of the vessel. This is disadvantageous because due to its salinity seawater is corrosive, and may influence the quality of the hydrocarbon products if leaking to the vessel cargo tanks.

According to a fifth aspect of the invention, a tempering system for heating and cooling hydrocarbon products in the tanks of the vessel is provided with a heat exchanger, the tempering system comprising a closed loop circulating a first cooling medium not being seawater and extending to cool/heat the hydrocarbon product and to the heat exchanger so as to exchange heat between the hydrocarbon product and a second medium, typically being seawater, flowing to the heat exchanger.

A preferred first cooling medium of the closed-loop cooling system comprises glycol at least as part of the cooling medium. Glycol is non-hazardous to the hydrocarbon product, but glycol is still readily detectable, if any leakage should occur of the closed-loop cooling system. Other first cooling mediums could be used as well, e.g. fresh water, gasses, oils, etc.

All the different aspects of the invention may be used in combination or individually. Further, the different aspects may be used in combination or individually in relation to hydrocarbons other than LPG, e.g. LNG, and in relation to other gasses having physical properties similar to LPG.

The invention further relates to a LPG carrier utilizing one of the above described aspects of the invention or any combination thereof.

CLAIMS

1. A cooling system for cooling hydrocarbon products in cargo tanks of a LPG carrier, said LPG carrier comprising a plurality of LPG cargo tanks within a hull of the vessel, where
- at least one first housing is provided containing a first compressor section for the cooling system, and where
- at least one second housing containing is provided containing a second compressor section for the cooling system,
- said at least first compressor section being connected by piping to a first part of a cooling system for cooling the hydrocarbon product in tanks of the vessel, said first part comprising a cargo tank or a set of cargo tanks, and
- said second compressor being connected by piping to a second part of the cooling system for cooling the hydrocarbon product in tanks of the vessel, said first part comprising at a cargo tank or a set of cargo tanks,
- said first part of the cooling system being provided nearer, viewed along the piping, to the first compressor section than to the second compressor section, and
- said second part of the cooling system being provided nearer, viewed along the piping, to the second compressor section than to the first compressor section.

2. A cooling system according to claim 1, wherein a compressor section is provided for each hull cargo tank of the LPG carrier, each compressor section being provided in an individual housing.

3. A gas containment system for collecting any residual gas of the hydrocarbon product from one or more tanks of a LPG carrier, where said gas containment system is intended for containment of gas subsequent to the main part of hydrocarbon product having been discharged.

4. A gas containment system according to claim 3, where said gas containment system comprises
- at least one individual containment tank for said gas containment system,
- said at least one individual containment tank being situated in at least one housing, and
- said at least one housing comprising at least one inlet for the gas of the hydrocarbon product being collected from one or more of the tanks of the vessel, and at least one outlet for the gas having been collected and stored in the individual containment tank.

5. A gas containment system according to claim 4, where said at least one housing is individual to the vessel and constitutes a shipping container having dimensions according to ISO (International Standard Organization), preferably a 20 feet ISO shipping container,

alternatively a 40 feet ISO shipping container, alternatively a shipping container of another ISO dimension.

6. A gas containment system according to claim 4 or claim 5, where at least two housings are provided,
- one of the at least two individual housings intended for containing one hydrocarbon product being collected from one or some tanks of the vessel, and
- another of the at least two individual housings intended for containing another hydrocarbon product collected from another or other of the tanks of the vessel.

7. A gas containment system according to claim 6, where both of said at least two housing are individual to the vessel and both of said two housings constitute a shipping container having dimensions according to ISO (International Standard Organization), preferably a 20 feet ISO shipping container, alternatively a 40 feet ISO shipping container, alternatively a shipping container of another ISO dimension.

8. A purging system for purging and rendering inert one or more cargo tanks of a LPG carrier, and where
- at least one inert gas producing unit of said purging system is situated in at least one housing,
- said housing comprising at least one outlet for the inert gas being inert to any hydrocarbon product carried by the vessel, and
- said housing is individual to the vessel and constitutes a shipping container having dimensions according to ISO (International Standard Organization), preferably a 20 feet ISO shipping container, alternatively a 40 feet ISO shipping container, alternatively a shipping container of another ISO dimension.

9. A purging system according to claim 8 said inert gas producing unit being a Nitrogen generator, and said purging system further comprising a compressor section for providing dry air to said inert gas producing unit, and said housing comprising at least one inlet for a connection for the dry air from said compressor section to said inert gas producing unit.

10. A tempering system for tempering hydrocarbon products in cargo tanks of a LPG carrier, said tempering system being provided with a heat exchanger and the tempering system comprising a closed loop circulating a first cooling medium not being seawater and extending to cool/heat the hydrocarbon product and to the heat exchanger so as to exchange heat between the hydrocarbon product and a second medium, typically being seawater, flowing to the heat exchanger

11. A tempering system according to claim 10, where the closed-loop cooling system comprises glycol at least as part of the first cooling medium.

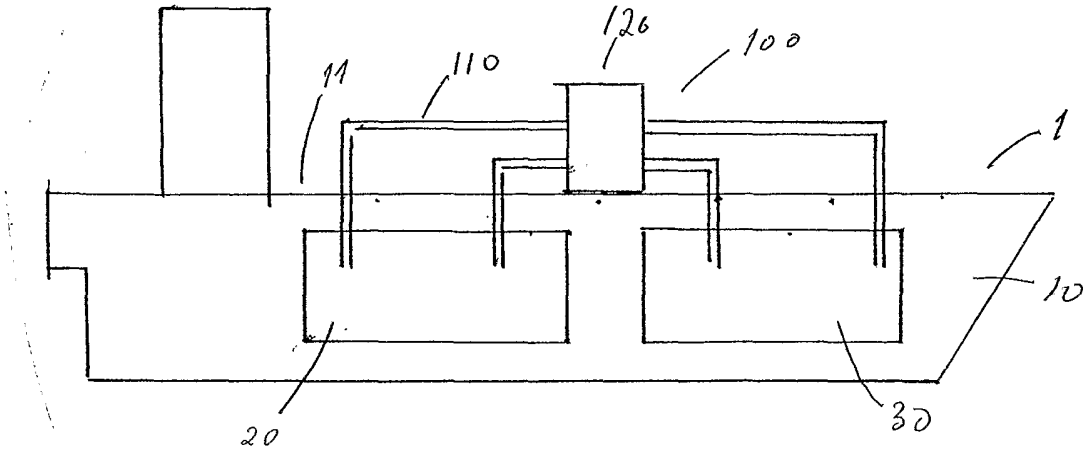

Fig. 1, prior art

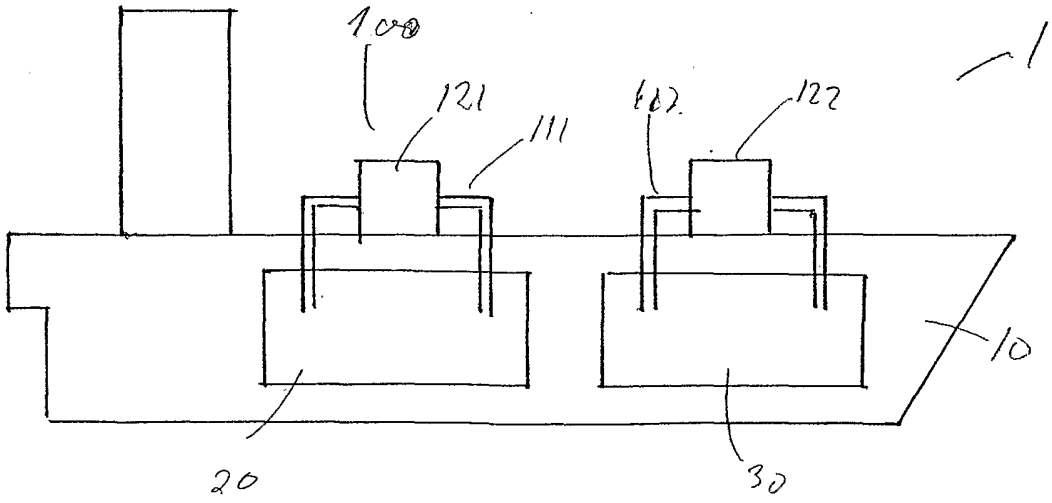

Fig. 2