

Description

Title of Invention

INTERMEDIATE FLUID TYPE VAPORIZER

Technical Field

[0001] The present invention relates to an intermediate fluid type vaporizer.

Background Art

[0002] Hitherto, as shown Patent Literature 1 below, there is known an intermediate fluid type vaporizer using an intermediate fluid in addition to a heat source fluid as an apparatus for vaporizing a low-temperature liquid such as LNG. Referring to FIG. 10, the intermediate fluid type vaporizer disclosed in Patent Literature 1 is provided with an intermediate fluid evaporator 81, an LNG evaporator 82, and a heater 83. Also, an inlet chamber 85, a large number of heat transfer tubes 86, an intermediate chamber 87, a large number of heat transfer tubes 88, and an outlet chamber 89 are provided in this order in the intermediate fluid type vaporizer as a channel through which seawater serving as the heat source fluid passes. The heat transfer tubes 86 are arranged in the heater 83, and the heat transfer tubes 88 are arranged in the intermediate fluid evaporator 81. An intermediate fluid (for example, propane) having a boiling point lower than the temperature of seawater is stored in the intermediate fluid evaporator 81.

[0003] The LNG evaporator 82 is provided with an inlet chamber 91, an outlet chamber 92, and a large number of heat transfer tubes 93 that provide connecting between the two chambers 91, 92. Each of the heat transfer tubes 93 has a substantially U-shape and protrudes in an upper part within the intermediate fluid evaporator 81. The outlet chamber 92 is in connecting with an inside of the heater 83 via an NG guide pipe 94.

[0004] In such a vaporizer, seawater serving as the heat source fluid passes through the inlet chamber 85, heat transfer tubes 86, intermediate chamber 87, and heat transfer tubes 88, and reaches the outlet chamber 89. At this time, the seawater flowing through the heat transfer tubes 88 undergoes heat exchange with the liquid intermediate fluid M within the intermediate fluid evaporator 81, so as to evaporate the intermediate fluid M.

[0005] On the other hand, the LNG serving as an object to be vaporized is fed from the inlet chamber 91 into the heat transfer tubes 93. Heat exchange performed between the LNG in the heat transfer tubes 93 and the evaporated intermediate fluid in the intermediate fluid evaporator 81 condenses the intermediate fluid M, and the LNG is evaporated in the heat transfer tubes 93 by receiving the heat of condensation so as to be turned into NG. The NG is fed from the outlet chamber 92 thorough the NG guide pipe 94 into the heater 83, where the NG is further heated by heat exchange with the seawater flowing through the heat transfer tubes 86 in the heater 83, and thereafter supplied to the using side.

[0006] The intermediate fluid type vaporizer disclosed in Patent Literature 1 is configured such that the LNG evaporator 82 has a large number of heat transfer tubes 93. For this reason, the LNG evaporator 82 has a considerable weight.

Citation List

Patent Literature

[0007] Patent Literature 1: Japanese Unexamined Patent Publication No. 2000-227200

Summary of Invention

[0008] An object of the present invention is to achieve weight reduction of an intermediate fluid type vaporizer.

[0009] An intermediate fluid type vaporizer according to one aspect of the present invention includes an intermediate fluid evaporation part that evaporates at least a part of a liquid intermediate fluid through heat exchange between a heat source medium and the intermediate fluid; and a liquefied gas vaporizing part that vaporizes a low-temperature liquefied gas by condensing the intermediate fluid evaporated by the intermediate fluid evaporation part to cause the vaporized gas to flow out, wherein the liquefied gas vaporizing part is configured by a stack-type heat exchanger having a stacked body which is formed with a first flow channel layer having first flow channels that are channels for flow of the intermediate fluid and a second flow channel layer having second flow channels that are channels for flow of the low-temperature liquefied gas, and the stack-type heat exchanger is installed in a posture where the first flow channels extend in an up-and-down direction or in a direction tilted relative to the up-and-down direction so that the intermediate fluid flows down in the first flow channels due to gravity.

Brief Description of Drawings

[0010] FIG. 1 is a view schematically showing a configuration of an intermediate fluid type vaporizer according to a first embodiment of the present invention.

FIG. 2 is a view schematically showing a configuration of an LNG evaporator provided in the intermediate fluid type vaporizer.

FIG. 3 is a view schematically showing a configuration of a stack-type heat exchanger constituting a heater that is provided in the intermediate fluid type vaporizer.

FIG. 4 is a view schematically showing a configuration of an intermediate fluid type vaporizer according to a modification of the first embodiment of the present invention.

FIG. 5 is a view schematically showing the configuration of the intermediate fluid type vaporizer according to the modification of the first embodiment of the present invention.

FIG. 6 is a view schematically showing the configuration of the intermediate fluid type vaporizer according to the modification of the first embodiment of the

present invention.

FIG. 7 is a view schematically showing the configuration of the intermediate fluid type vaporizer according to the modification of the first embodiment of the present invention.

FIG. 8 is a view schematically showing a configuration of an intermediate fluid type vaporizer according to a second embodiment of the present invention.

FIG. 9 is a view schematically showing a configuration of an intermediate fluid type vaporizer according to a modification of the second embodiment of the present invention.

FIG. 10 is a view schematically showing a configuration of a conventional intermediate fluid type vaporizer.

Description of Embodiments

[0011] Hereafter, embodiments for carrying out the present invention will be described in detail with reference to the drawings.

[0012] (First embodiment)

Referring to FIG. 1, an intermediate fluid type vaporizer 10 according to a first embodiment (hereafter simply referred to as a vaporizer) is a device that transfers heat of seawater, which is a heat source medium, to a liquefied natural gas (LNG), which is a low-temperature liquefied gas, via an intermediate fluid M so as to vaporize the LNG to obtain natural gas (NG). As the intermediate fluid M, propane or the like can be used, for example. Here, the vaporizer 10 may be configured as a device that vaporizes or heats a low-temperature liquefied gas other than LNG, such as a liquefied petroleum gas (LPG) or liquid nitrogen (LN₂).

[0013] The vaporizer 10 includes an intermediate fluid evaporator E1 which is an intermediate fluid evaporation part, an LNG evaporator E2 which is a liquefied gas vaporizing part, and a heater E3. The LNG evaporator E2 is arranged within a shell 11 of the intermediate fluid evaporator E1. Further, the heater E3 is arranged at a place lateral to the shell 11. An intermediate chamber 14 is formed between the shell 11 and the heater E3.

[0014] The shell 11 has a shape that is long in a horizontal direction. A large number of heat transfer tubes 20 of the intermediate fluid evaporator E1 are arranged in a lower part within the shell 11. The LNG evaporator E2 is arranged in an upper part within the shell 11.

[0015] The intermediate chamber 14 is arranged adjacent to one of a pair of sidewalls constituting the shell 11 of the intermediate fluid evaporator E1, and an outlet chamber 18 is arranged adjacent to the other one of the pair of sidewalls. The heat transfer tubes 20 are arranged in a lower part of a space within the shell 11. The heat transfer tubes 20 are arranged to bridge between a first sidewall 11a, which is one of the pair of opposing sidewalls constituting the shell 11 of the intermediate fluid evaporator E1 and functions as a partition wall between the

intermediate chamber 14 and the inside of the shell 11, and a second sidewall 11b, which is the other one of the pair of opposing sidewalls constituting the shell 11 of the intermediate fluid evaporator E1 and functions as a partition wall between the outlet chamber 18 and the inside of the shell 11. These heat transfer tubes 20 each have a shape that extends linearly in one direction; however, the shape is not limited to this one alone. The inside of each of the heat transfer tubes 20 is in communication with the intermediate chamber 14 and the outlet chamber 18.

[0016] A discharge pipe 24 that discharges the seawater is connected to the outlet chamber 18. The seawater in the outlet chamber 18 is discharged to the outside through the discharge pipe 24.

[0017] The intermediate fluid (for example, propane) M having a boiling point lower than the temperature of seawater is stored in the shell 11. The intermediate fluid M is stored to such a degree that the liquid level is positioned above all of the heat transfer tubes (heat transfer tubes through which the heat source fluid, for example, seawater, flows) 20.

[0018] An inlet chamber 26 for introducing the LNG and an outlet chamber 28 for guiding the NG out are arranged above the outlet chamber 18. A supply tube 30 for feeding the LNG is connected to the inlet chamber 26. A guide-out tube 32 for guiding the NG out is connected to the outlet chamber 28. Here, it is depicted in FIG. 1 that the outlet chamber 28 is positioned above the inlet chamber 26 for the sake of convenience; however, actually, the outlet chamber 28 and the inlet chamber 26 are laterally arranged by a configuration of a microchannel heat exchanger described later. However, the present embodiment is not limited to this configuration alone.

[0019] Referring to FIG. 2, the LNG evaporator E2 is configured by a microchannel heat exchanger which is one example of a stack-type heat exchanger having a stacked body 38 in which first flow channels 41a and second flow channels 42a are formed. Specifically, the microchannel heat exchanger has a configuration in which the stacked body 38 of flow channel layers 41, 42 made of metal plates is interposed between end plates 43, 43. This stacked body 38 has a configuration in which the first flow channel layer 41 having numerous flow channels (first flow channels) 41a, through which the intermediate fluid M flows, concaved thereon and the second flow channel layer 42 having numerous flow channels (second flow channels) 42a, through which the LNG flows, concaved thereon are alternately stacked. Further, heat exchange is performed between the intermediate fluid M that flows through each of the first flow channels 41a and the LNG that flows through each of the second flow channels 42a, whereby the LNG is heated to be vaporized.

[0020] The first flow channel layer 41 and the second flow channel layer 42 are each in an upright posture and in a posture extending in a direction (horizontal direction) parallel to the direction in which the heat transfer tubes 20 of the intermediate fluid

evaporator E1 extend. However, the posture of the flow channel layers 41, 42 is not limited to the upright posture but may be a tilted posture. Further, the flow channel layers 41, 42 may be in a posture extending in a direction that intersects with the direction in which the heat transfer tubes 20 extend instead of being in a posture parallel to the direction in which the heat transfer tubes 20 extend.

[0021] The first flow channels 41a are each formed to extend in an up-and-down direction and are arranged to be aligned in a longitudinal direction of the first flow channel layer 41. A header is not provided above the stacked body 38. Accordingly, the upper ends of the first flow channels 41a are open into the shell 11. For this reason, the gaseous intermediate fluid M within the shell 11 flows directly into the first flow channels 41a without the intermediary of a header.

[0022] Here, the posture of the first flow channels 41a is not limited to a configuration extending in an upright direction but may be formed in a shape extending in a direction tilted with respect to the up-and-down direction. Also, the shape of the first flow channels 41a is not limited to a linearly extending shape but may have a configuration of being bent or meandering in the midway. In essence, it is sufficient that the first flow channels 41a are configured so that the intermediate fluid M flows down in the first flow channels 41a from a flow-in end to a flow-out end due to gravity and flows out from the flow-out end.

[0023] A liquid reservoir 45 is provided below the stacked body 38. The liquid reservoir 45 stores the intermediate fluid M condensed in the first flow channels 41a and is directly coupled to a lower end of the stacked body 38. The liquid reservoir 45 is formed to have a shape that covers the whole lower surface of the stacked body 38 so that the inside space of the liquid reservoir 45 is in communication with all of the first flow channels 41a. In other words, the liquid intermediate fluid M is stored on a downstream side of the first flow channels 41a. A space below the lower ends of the first flow channels 41a is filled by the liquid intermediate fluid M stored in the liquid reservoir 45. Here, a gas layer may be present or may not be present between the liquid intermediate fluid M stored at the lower ends within the first flow channels 41a and the liquid intermediate fluid M stored in the liquid reservoir 45. This may change depending on operation conditions. In any state, the liquid intermediate fluid M is stored at a lower side of the first flow channels 41a, so that the gaseous intermediate fluid M is prevented from being sucked from the lower side of the first flow channels 41a.

[0024] A liquid sealing tube 46 is connected to a bottom surface of the liquid reservoir 45. The liquid sealing tube 46 extends downwards from the bottom surface of the liquid reservoir 45. A lower end of the liquid sealing tube 46 is dipped in the intermediate fluid M stored in the intermediate fluid evaporator E1. In more detail, the lower end of the liquid sealing tube 46 is dipped in the intermediate fluid M and arranged above each of the heat transfer tubes 20 of the intermediate fluid

evaporator E1. In other words, the liquid sealing tube 46 connects between a lower part of the LNG evaporator E2 and an upper part of the intermediate fluid evaporator E1. Accordingly, the bottom surface of the liquid reservoir 45 is disposed at a position spaced apart above from the liquid level of the intermediate fluid M stored in the intermediate fluid evaporator E1. For this reason, the LNG evaporator E2 is positioned above the liquid level of the intermediate fluid evaporator E1.

[0025] The inside of the liquid reservoir 45 and the inside of the liquid sealing tube 46 are filled with the liquid intermediate fluid M. In other words, the liquid sealing tube 46 connects between the liquid intermediate fluid M stored in the liquid reservoir 45 and the liquid level of the liquid intermediate fluid M stored in the intermediate fluid evaporator E1. The liquid sealing tube 46 has a cross-sectional area that is sufficiently smaller than the area of the bottom surface of the liquid reservoir 45.

[0026] The second flow channels 42a are each formed to extend in a direction perpendicular to the first flow channels 41a, specifically in a longitudinal direction of the second flow channel layer 42, and are arranged to be aligned in an up-and-down direction. Here, the shape of the second flow channels 42a is not limited to a straightly extending shape but may be bent or meandering in the midway.

[0027] The flow channels 41a, 42a are formed, for example, by etching metal plates 41, 42 and are formed each in a groove shape having a semicircular cross-section. The flow channels 41a, 42a each have a flow channel width of, for example, 0.2 mm to 3 mm.

[0028] In the present embodiment, two sets of stacked bodies 38 of flow channel layers 41, 42 interposed between the end plates 43, 43 are provided. Then, in one of the two sets, the LNG flows from the front to the rear of FIG. 2, while in the other one of the two sets, the LNG that has passed through the one set flows from the rear to the front of FIG. 2. In other words, the present embodiment has a configuration with two passes. The liquid reservoir 45 is formed to have a size enabling communication to the first flow channels 41a of the two passes. Here, instead of this configuration, the liquid reservoir 45 may have a configuration in which a first liquid reservoir connected to the first flow channels 41a within the stacked body 38 constituting the first pass and a second liquid reservoir connected to the first flow channels 41a within the stacked body 38 constituting the second pass are separately provided. In this case, the liquid sealing tube 46 has a configuration provided with a first liquid sealing tube connected to the first liquid reservoir and a second liquid sealing tube connected to the second liquid reservoir.

[0029] A header is provided on each of the rear side and the front side of FIG. 2 (See FIG. 1). Here, in FIG. 2, depiction of headers on the front side (distributing header 48 and gathering header 50) is omitted for the sake of convenience. As the headers,

a distributing header 48 that distributes the LNG fed through the inlet chamber 26 to each of the second flow channels 42a (See FIG. 1), a connecting header 49 that gathers the LNG that has flowed through each of the second flow channels 42a within the stacked body 38 of the first set and distributes the gathered LNG to each of the second flow channels 42a within the stacked body 38 of the second set, and a gathering header 50 that gathers the NG that has flowed through each of the second flow channels 42a within the stacked body 38 of the second set and guides the gathered NG to the outlet chamber 28 (See FIG. 1) are provided. Here, it is depicted in FIG. 1 that the distributing header 48 and the gathering header 50 are arranged to be aligned in an up-and-down direction; however, actually, these headers are arranged to be laterally aligned.

[0030] Here, the present embodiment has a configuration in which the microchannel heat exchanger (LNG evaporator E2) has two passes; however, the present embodiment is not limited to this, and the microchannel heat exchanger may have a configuration with one pass or with three or more passes. Also, the stack-type heat exchanger (LNG evaporator E2) is not limited to a case of being configured by a microchannel heat exchanger. For example, the stack-type heat exchanger may be configured by a plate fin heat exchanger in which numerous metal plates formed in an undulating shape are stacked, and spaces between adjacent metal plates are formed as the first flow channels and second flow channels.

[0031] Returning to FIG. 1, the heater E3 is connected to the guide-out tube 32. The intermediate chamber 14 is formed between a case body 52 of the heater E3 and the shell 11. An inlet chamber 53 for the heat source medium such as seawater is provided on a sidewall of the case body 52 located opposite to the shell 11. The heat source medium such as seawater is fed into the inlet chamber 53.

[0032] Numerous heat transfer tubes 54 (heat transfer tube type heat exchanger E3b) through which the heat source medium such as seawater passes and a stack-type heat exchanger E3a into which the NG is fed from the guide-out tube 32 are installed in the case body 52. Also, an intermediate fluid M2 is enclosed in the case body 52 of the heater E3. The intermediate fluid M2 is made of, for example, propane. The heat transfer tubes 54 are formed to bridge between the sidewall adjacent to the intermediate chamber 14 and the sidewall adjacent to the inlet chamber 53. The heat transfer tubes 54 are disposed below the liquid level of the liquid intermediate fluid M2 stored in the case body 52, and the stack-type heat exchanger E3a is disposed above the liquid level.

[0033] In the present embodiment, the stack-type heat exchanger E3a of the heater E3 is configured by a microchannel heat exchanger and has a configuration similar to that of the LNG evaporator E2. As shown in FIG. 3, the stack-type heat exchanger E3a within the heater E3 also is configured such that a stacked body having a first flow channel layer 56 and a second flow channel layer 57 is provided

between end plates 58, 58. In the first flow channel layer 56, first flow channels 56a, through which the intermediate fluid M2 flows, are formed. In the second flow channel layer 57, second flow channels (not illustrated in the drawings), through which the LN flows, are formed. Upper ends of the first flow channels 56a are open to an upper surface of the stacked body. The second flow channels extend in a direction perpendicular to the first flow channels 56a.

[0034] In the stack-type heat exchanger E3a, headers 61, 62 are provided on a pair of side surfaces that are oriented in directions opposite to each other. For example, the header on the front side shown in FIG. 3 is a flow-in side header 61 that is connected to the guide-out tube 32. A flow-out side header 62 that gathers the NG that has flowed through the second flow channels and causes the gathered NG to flow out is provided on a side opposite to the flow-in side header 61. In the present embodiment, the stack-type heat exchanger E3a is configured with one pass, so that the headers 61, 62 are separately provided on two side surfaces, that is, on the front and rear side surfaces. However, the configuration is not limited to one pass alone, and the stack-type heat exchanger E3a may be configured with two or more passes.

[0035] A liquid reservoir 59 and a liquid sealing tube 63 are provided in the stack-type heat exchanger E3a in the same manner as in the LNG evaporator E2. The liquid reservoir 59 is disposed below the stacked body, and the liquid sealing tube 63 is connected to a bottom surface of the liquid reservoir 59. The liquid reservoir 59 is formed to have a shape that covers the whole lower surface of the stacked body so that the inside space of the liquid reservoir 59 is in communication with all of the first flow channels 56a. A space below the lower ends of the first flow channels 56a is filled by the liquid intermediate fluid M2 stored in the liquid reservoir 59. The liquid sealing tube 63 extends downwards from the bottom surface of the liquid reservoir 59. A lower end of the liquid sealing tube 63 is dipped in the intermediate fluid M2 stored in the case body 52. Here, a gas layer may be present or may not be present between the liquid intermediate fluid M2 stored at the lower ends within the first flow channels 56a and the liquid intermediate fluid M2 stored in the liquid reservoir 59.

[0036] The NG flows into the flow-in side header 61 through the guide-out tube 32 and is branched and distributed to each of the second flow channels through the flow-in side header 61. The NG in each of the second flow channels is heated by the intermediate fluid M2 in the first flow channels 56a. This NG flows into the flow-out side header 62 and thereafter supplied to the user through a discharge pipe 65.

[0037] Here, an operation of the vaporizer 10 according to the first embodiment will be described.

[0038] The liquid intermediate fluid M that is stored in the lower part within the shell 11 is heated by the seawater that flows into each of the heat transfer tubes 20

through the intermediate chamber 14 and the intermediate fluid M is evaporated. Here, the seawater flows out from the heat transfer tubes 20 and discharged to the outside through the outlet chamber 18 and the discharge pipe 24.

[0039] The evaporated intermediate fluid M undergoes heat exchange with the LNG in the LNG evaporator E2 located in an upper part within the shell 11. Specifically, in the LNG evaporator E2, heat exchange is performed between the intermediate fluid M within the first flow channels 41a and the LNG within the second flow channels 42a, whereby the gaseous intermediate fluid M is condensed, and the LNG is evaporated. At this time, the pressure within the first flow channels 41a decreases to be lower than the pressure around the microchannel heat exchanger due to condensation of the intermediate fluid M. Since the space located below the lower ends of the first flow channels 41a is filled by the liquid intermediate fluid M stored in the liquid reservoir 45 and the liquid sealing tube 46, a head (differential pressure) in accordance with the difference in height between the liquid level of the liquid intermediate fluid stored in the liquid reservoir 45 and the liquid sealing tube 46 and the liquid level of the liquid intermediate fluid stored in the intermediate fluid evaporator E1 is applied as a flow-in suction force to suck the intermediate fluid into the first flow channels 41a. For this reason, the gaseous intermediate fluid M is sucked into the first flow channels 41a through an opening at the upper ends of the first flow channels 41a and is not sucked from the lower ends of the first flow channels 41a. This generates a flow movement in the first flow channels 41a in a direction in which the intermediate fluid M flows down. The intermediate fluid M that has flowed down through the first flow channels 41a is stored in the liquid reservoir 45. In this manner, in the shell 11, circulation of the intermediate fluid M between the intermediate fluid evaporator E1 and the LNG evaporator E2 is repeated.

[0040] The NG vaporized in the LNG evaporator E2 passes through the outlet chamber 28 and flows through the guide-out tube 32 to be fed into the heater E3. In the heater E3, the NG flows into the second flow channels of the stack-type heat exchanger E3a from the guide-out tube 32 through the flow-in side header 61. The NG in the second flow channels is heated by the intermediate fluid M2 flowing through the first flow channels 56a and passes through the flow-out side header 62 and the discharge pipe 65 to be supplied to the user.

[0041] In the heater E3 as well, the intermediate fluid M2 flows down from above to below in the first flow channels 56a of the stack-type heat exchanger E3a. In other words, in the stack-type heat exchanger E3a of the heater E3 as well, a head (differential pressure) in accordance with the difference in height between the liquid level of the liquid intermediate fluid M2 stored in the liquid reservoir 59 and the liquid level of the liquid intermediate fluid M2 stored in the case body 52 is applied as a flow-in suction force to suck the intermediate fluid M2 into the first flow

channels 56a in the same manner as in the LNG evaporator E2.

[0042] As described above, in the present embodiment, the LNG evaporator E2 is provided with a stack-type heat exchanger, so that the LNG evaporator E2 can be reduced in scale and weight as compared with a case in which the LNG evaporator E2 is formed by a multitubular heat exchanger. Moreover, since the stack-type heat exchanger is configured such that the intermediate fluid M flows down in the first flow channels 41a due to gravity, the pressure in the first flow channels 41a decreases due to condensation of the intermediate fluid M in the first flow channels 41a in the stack-type heat exchanger, so that the gaseous intermediate fluid M is more likely to flow into the first flow channels 41a. Accordingly, there is no need to provide means for pressing the intermediate fluid M into the first flow channels 41a even in a case in which the LNG evaporator E2 is configured by a stack-type heat exchanger having a stacked body 38 in which first flow channels 41a and second flow channels 42a are formed.

[0043] Moreover, in the present embodiment, the LNG evaporator E2 is provided with the liquid reservoir 45, so that the space below the lower ends of the first flow channels 41a is filled by the liquid intermediate fluid M. For this reason, the intermediate fluid M is prevented from flowing into the first flow channels 41a from these downstream-side ends. Accordingly, the intermediate fluid M flows into the first flow channels 41a in one direction, so that the flow of the intermediate fluid M in the first flow channels 41a can be obtained easily. Therefore, the intermediate fluid M can be readily circulated between the intermediate fluid evaporator E1 and the LNG evaporator E2.

[0044] Further, in the present embodiment, the liquid sealing tube 46 is provided to connect between the liquid reservoir 45 and the liquid level of the liquid intermediate fluid M stored in the intermediate fluid evaporator E1, and the inside of the liquid sealing tube 46 is filled with the liquid intermediate fluid M. For this reason, the liquid intermediate fluid M stored in the liquid reservoir 45 and the liquid intermediate fluid M stored in the intermediate fluid evaporator E1 are connected through the intermediary of the liquid sealing tube 46. Further, when the pressure in the first flow channels 41a goes down due to condensation of the intermediate fluid M in the first flow channels 41a, a head (differential pressure) according to the difference in height between the liquid level of the liquid intermediate fluid M stored in the liquid reservoir 45 and the liquid level of the liquid intermediate fluid M stored in the intermediate fluid evaporator E1 is applied as a flow-in suction force to suck the intermediate fluid M into the first flow channels 41a. The distance between the liquid level in the liquid reservoir 45 and the liquid level in the intermediate fluid evaporator E1 can be increased in accordance with the length of the liquid sealing tube 46, so that the suction force of sucking into the first flow channels 41a can be increased in accordance with this distance. Further, since

the liquid reservoir 45 is connected to the liquid level in the intermediate fluid evaporator E1 through the intermediary of the liquid sealing tube 46, decrease in the evaporation surface of the intermediate fluid M can be suppressed as compared with a case in which the liquid reservoir 45 is directly connected to the liquid level.

[0045] Also, in the present embodiment, the LNG evaporator E2 is disposed in the shell 11 of the intermediate fluid evaporator E1. For this reason, the intermediate fluid M circulates between the intermediate fluid evaporator E1 and the LNG evaporator E2 in the shell 11. For this reason, the flow resistance until the intermediate fluid M evaporated in the intermediate fluid evaporator E1 is sucked into the first flow channels 41a can be reduced. Accordingly, the intermediate fluid M can be more readily subjected to natural circulation.

[0046] Also, in the present embodiment, the stack-type heat exchanger of the LNG evaporator E2 is a microchannel heat exchanger. For this reason, the LNG evaporator E2 can be reduced in scale and weight.

[0047] In the aforementioned embodiment, description has been given on a configuration provided with the liquid reservoir 45 and the liquid sealing tube 46; however, the liquid reservoir 45 and the liquid sealing tube 46 may be omitted, as shown in FIG. 4, and the LNG evaporator E2 may be disposed above the liquid level of the intermediate fluid M. Alternatively, referring to FIG. 5, only the liquid sealing tube 46 may be omitted, and the LNG evaporator E2 and the liquid reservoir 45 may be disposed above the liquid level of the intermediate fluid M.

[0048] Also, referring to FIG. 6, the liquid sealing tube 46 may be omitted, and the liquid reservoir 45 may be in direct contact with the intermediate fluid M stored in the intermediate fluid evaporator E1. In this configuration, the intermediate fluid M in the liquid reservoir 45 and the intermediate fluid M stored in the intermediate fluid evaporator E1 are connected through an opening formed in the liquid reservoir 45. Accordingly, in this embodiment as well, though the difference in height between the liquid level of the liquid intermediate fluid M stored in the liquid reservoir 45 and the liquid level of the liquid intermediate fluid M stored in the intermediate fluid evaporator E1 is not large, a suction force of sucking the intermediate fluid M corresponding to the head (differential pressure) according to the difference can be obtained.

[0049] Also, the liquid sealing tube 63 provided in the stack-type heat exchanger E3a in the heater E3 can be omitted in the same manner, and the liquid reservoir 59 in the heater E3 can be directly dipped into the liquid level of the intermediate fluid M2 in the heater E3. Also, it is possible to adopt a configuration in which the liquid reservoir 59 is omitted.

[0050] In the aforementioned embodiment, the heater E3 is configured as an intermediate fluid type heat exchanger, and the stack-type heat exchanger E3a is provided; however, the embodiment is not limited to this alone. For example,

referring to FIG. 7, the stack-type heat exchanger E3a may be omitted, and the NG fed into the case body 52 of the heater E3 through the guide-out tube 32 and the heat source medium such as seawater flowing in the heat transfer tubes may be directly subjected to heat exchange. In this configuration, the heater E3 is configured as a multitubular heat exchanger in which the inside of the case body 52 is filled with the NG, and the heat transfer tubes are installed therein.

[0051] Also, the aforesaid embodiment has a configuration in which the heater E3 is provided; however, it is possible to adopt a configuration in which the heater E3 is omitted. In this case, the intermediate chamber 14 also is unnecessary.

[0052] (Second embodiment)

FIG. 8 shows a second embodiment of the present invention. Here, (though specifically described below), the same constituent elements as appear in the first embodiment will be denoted with the same reference symbols, and the detailed description thereof will be omitted.

[0053] In the first embodiment, the LNG evaporator E2 is disposed in the shell 11 of the intermediate fluid evaporator E1; however, in the second embodiment, the LNG evaporator E2 is disposed outside of a shell 67 of the intermediate fluid evaporator E1, and a circulation pipe 66 that connects the LNG evaporator E2 and the intermediate fluid evaporator E1 with each other is provided. The circulation pipe 66 has a first pipe 66a that connects between the upper surface of the shell 67 of the intermediate fluid evaporator E1 and the upper surface of a header 68 (described later) of the LNG evaporator E2 and a second pipe 66b that extends from the lower surface of the liquid reservoir 45 into the shell 67.

[0054] The intermediate fluid evaporator E1 includes numerous heat transfer tubes 20 provided in the shell 67. The inside of the shell 67 is filled with the liquid intermediate fluid M to such a position that all the heat transfer tubes 20 are dipped.

[0055] The LNG evaporator E2 has a configuration in which the liquid reservoir 45 is provided at the lower surface, and the header 68 is provided at the upper surface. The lower surface of the header 68 is formed to have an open hollow shape. An introduction inlet for introducing the intermediate fluid M flowing through the first pipe 66a is formed in the upper surface of the header 68. The gaseous intermediate fluid M that has flowed into the header 68 through the introduction inlet flows into each of the first flow channels 41a within the stacked body 38. In the present embodiment, the LNG evaporator E2 is configured by a microchannel heat exchanger; however, the present embodiment is not limited to this, and the LNG evaporator E2 may be configured, for example, by a plate fin heat exchanger.

[0056] The second pipe 66b functions as a liquid sealing tube. The second pipe 66b extends into the shell 67, and the lower end of the second pipe 66b is positioned below the liquid level of the liquid intermediate fluid M in the intermediate fluid

evaporator E1. In other words, the liquid intermediate fluid M fills the space from the liquid level in the intermediate fluid evaporator E1 over to the second pipe 66b and the liquid reservoir 45.

[0057] In the present embodiment, in the heater E3 as well, a stack-type heat exchanger E3a is disposed outside of a case body 70 of a heat transfer tube type heat exchanger E3b. In other words, the heater E3 is configured by an intermediate fluid type heat exchanger and includes the heat transfer tube type heat exchanger E3b that performs heat exchange between a heat source medium (for example, seawater) and an intermediate fluid M2, the stack-type heat exchanger E3a that performs heat exchange between the intermediate fluid M2 and the NG, and a connection pipe 69 that connects the heat transfer tube type heat exchanger E3b and the stack-type heat exchanger E3a with each other. The connection pipe 69 has a first connection pipe 69a that connects between the upper surface of the case body 70 of the heat transfer tube type heat exchanger E3b and the upper surface of a header 72 (described later) of the stack-type heat exchanger E3a and a second connection pipe 69b that extends from the lower surface of the liquid reservoir 59 to the liquid level within the case body 70 of the heat transfer tube type heat exchanger E3b.

[0058] The heat transfer tube type heat exchanger E3b has numerous heat transfer tubes 54 installed in the case body 70, and the heat source medium such as seawater flows through the inside of the heat transfer tubes 54. The inside of the case body 70 is filled with the liquid intermediate fluid M2 to such a position that all the heat transfer tubes 54 are dipped.

[0059] The stack-type heat exchanger E3a has a configuration in which the liquid reservoir 59 is provided at the lower surface, and the header 72 is provided at the upper surface. The lower surface of the header 72 is formed to have an open hollow shape. An introduction inlet for introducing the intermediate fluid M flowing through the first connection pipe 69a is formed in the upper surface of the header 72. The gaseous intermediate fluid M that has flowed into the header 72 through the introduction inlet flows into each of the first flow channels 56a within the stacked body.

[0060] In the present embodiment, the stack-type heat exchanger E3a is configured by a microchannel heat exchanger; however, the present embodiment is not limited to this, and the stack-type heat exchanger E3a may be configured, for example, by a plate fin heat exchanger.

[0061] In the second embodiment, the liquid intermediate fluid M is condensed by undergoing heat exchange with the LNG in the LNG evaporator E2. This lowers the pressure within the first flow channels 41a of the LNG evaporator E2, so that the gaseous intermediate fluid M evaporated in the intermediate fluid evaporator E1 is sucked into the LNG evaporator E2 through the first pipe 66a. The liquid intermediate fluid M condensed in the LNG evaporator E2 is stored in the liquid

reservoir 45. Since the liquid intermediate fluid M is stored also in the second pipe 66b, the lower side of the first flow channels 41a is filled by the liquid intermediate fluid M. Accordingly, the force by which the liquid intermediate fluid M within the liquid reservoir 45 and the second pipe 66b tends to descend is applied as a suction force to suck the gaseous intermediate fluid M into the first flow channels 41a. This generates a flow movement of the intermediate fluid M from the first pipe 66a into the LNG evaporator E2.

[0062] The NG gasified in the LNG evaporator E2 is fed into the stack type heat exchanger E3a of the heater E3 through the guide-out tube 32. The NG is heated by the intermediate fluid M2 in the stack type heat exchanger E3a and supplied to the using side. Natural circulation of the intermediate fluid M2 occurs also between the stack type heat exchanger E3a and the heat transfer tube type heat exchanger E3b in the same manner as the circulation between the intermediate fluid evaporator E1 and the LNG evaporator E2.

[0063] According to the second embodiment, the shell 67 of the intermediate fluid evaporator E1 can be reduced in scale. Also, since the intermediate fluid evaporator E1 does not become an encumbrance, the checking and the like can be easily carried out when the stack-type heat exchanger (LNG evaporator E2) is in a state of being abnormal.

[0064] Here, the second embodiment has a configuration in which the second pipe 66b extends into the shell 67, and the lower end of the second pipe 66b is positioned below the liquid level of the liquid intermediate fluid M within the intermediate fluid evaporator E1; however, the lower end of the second pipe 66b may be positioned above the liquid level of the intermediate fluid M. In this case, the second pipe 66b does not function as a liquid sealing tube. The same applies to the heat transfer tube type heat exchanger E3b of the heater E3. In other words, the second embodiment has a configuration in which the second connection pipe 69b extends into the case body 70, and the lower end of the second connection pipe 69b is positioned below the liquid level of the liquid intermediate fluid M2 within the case body 70 of the heat transfer tube type heat exchanger E3b; however, the lower end of the second connection pipe 69b may be positioned above the liquid level of the liquid intermediate fluid M2.

[0065] In the second embodiment, the heater E3 may be configured as a multitubular heat exchanger E3b in the same manner as in the configuration of FIG. 7. In other words, referring to FIG. 9, a configuration may be adopted in which the stack-type heat exchanger E3a constituting the heater E3 is omitted, and seawater serving as the heat source medium and the NG undergo heat exchange directly in the heat transfer tubes.

[0066] Here, description of the other constituent elements, functions, and effects will be omitted; however, these are the same as those in the first embodiment and

modifications thereof.

[0067] Here, the intermediate fluid type vaporizer according to the above embodiments will be schematically described.

[0068] The intermediate fluid type vaporizer described above is provided with an intermediate fluid evaporation part that evaporates at least a part of a liquid intermediate fluid through heat exchange between a heat source medium and the intermediate fluid; and a liquefied gas vaporizing part that vaporizes a low-temperature liquefied gas by condensing the intermediate fluid evaporated in the intermediate fluid evaporation part to cause a vaporized gas to flow out, wherein the liquefied gas vaporizing part is configured by a stack-type heat exchanger having a stacked body which is formed with a first flow channel layer having first flow channels that are channels for flow of the intermediate fluid and a second flow channel layer having second flow channels that are channels for flow of the low-temperature liquefied gas, and the stack-type heat exchanger is installed in a posture where the first flow channels extend in an up-and-down direction or in a direction tilted relative to the up-and-down direction so that the intermediate fluid flows down in the first flow channels due to gravity.

[0069] In the present intermediate fluid type vaporizer, the liquefied gas vaporizing part is configured by a stack-type heat exchanger, so that the liquefied gas vaporizing part can be reduced in scale and weight as compared with a case in which the liquefied gas vaporizing part is formed of a multitubular heat exchanger.

Moreover, since the stack-type heat exchanger is configured such that the intermediate fluid flows down in the first flow channels due to gravity, the pressure in the first flow channels decreases due to condensation of the intermediate fluid in the first flow channels in the stack-type heat exchanger, so that the gaseous intermediate fluid is more likely to flow into the first flow channels. Accordingly, there is no need to provide means for pressing the intermediate fluid into the first flow channels even in a case in which the liquefied gas vaporizing part is configured by a stack-type heat exchanger having a stacked body in which first flow channels and second flow channels are formed. From this point as well, weight reduction of the intermediate fluid type vaporizer can be achieved.

[0070] The liquefied gas vaporizing part may be provided with a liquid reservoir that stores the liquid intermediate fluid on a downstream side of the first flow channels.

[0071] In this embodiment, the gaseous intermediate fluid can be prevented from flowing into the first flow channels from the downstream-side ends of the first flow channels. Accordingly, the intermediate fluid flows into the first flow channels in one direction, so that formation of a downward flow of the intermediate fluid in the first flow channels is promoted. Therefore, the intermediate fluid can be more readily circulated between the intermediate fluid evaporation part and the liquefied gas vaporizing part.

[0072] The intermediate fluid evaporation part may be positioned below the liquefied gas vaporizing part. In this case, the intermediate fluid type vaporizer may be further provided with a liquid sealing tube that connects between the liquid reservoir and a liquid level of the liquid intermediate fluid stored in the intermediate fluid evaporation part.

[0073] In this embodiment, the inside of the liquid sealing tube is filled with the liquid intermediate fluid, whereby the liquid intermediate fluid stored in the liquid reservoir and the liquid intermediate fluid stored in the intermediate fluid evaporation part are connected through the intermediary of the liquid sealing tube. Further, when the pressure in the first flow channels goes down due to condensation of the intermediate fluid in the first flow channels, a head (differential pressure) according to the difference in height between the liquid level of the liquid intermediate fluid stored in the liquid reservoir and the liquid level of the liquid intermediate fluid stored in the intermediate fluid evaporation part is applied as a flow-in suction force to suck the intermediate fluid into the first flow channels. At this time, the distance between the liquid level in the liquid reservoir and the liquid level in the intermediate fluid evaporation part can be increased in accordance with the length of the liquid sealing tube, so that the suction force of sucking into the first flow channels can be increased in accordance with this distance. Further, since the liquid level in the liquid reservoir is connected to the liquid level in the intermediate fluid evaporation part through the intermediary of the liquid sealing tube, decrease in the evaporation surface of the intermediate fluid in the intermediate fluid evaporation part can be suppressed as compared with a case in which the liquid reservoir is directly in contact with the liquid level of the intermediate fluid evaporation part.

[0074] The liquefied gas vaporizing part may be disposed within the shell of the intermediate fluid evaporation part.

[0075] In this embodiment, the intermediate fluid circulates between the intermediate fluid evaporation part and the liquefied gas vaporizing part in the shell. For this reason, the flow resistance until the intermediate fluid evaporated in the intermediate fluid evaporation part is sucked into the first flow channels can be reduced. Accordingly, the intermediate fluid can be more readily subjected to natural circulation.

[0076] The liquefied gas vaporizing part may be disposed outside the shell of the intermediate fluid evaporation part, and the intermediate fluid type vaporizer may be further provided with a circulation pipe that connects between the liquefied gas vaporizing part and the shell of the intermediate fluid evaporation part. In this embodiment, the shell of the intermediate fluid evaporation part can be reduced in scale. Also, since the intermediate fluid evaporation part does not become an encumbrance, the checking and the like of the stack-type heat exchanger can be

easily carried out when the stack-type heat exchanger is in a state of being abnormal.

[0077] The stack-type heat exchanger may be a microchannel heat exchanger. In this embodiment, the liquefied gas vaporizing part can be reduced in scale and weight. Here, the microchannel heat exchanger is a heat exchanger that is provided with a stacked body formed by stacking numerous metal plates excellent in heat transfer characteristics. This stacked body has a configuration in which a flow channel layer made of a metal plate and having a flow channel, through which the intermediate fluid flows, concaved thereon and a flow channel layer made of a metal plate and having a flow channel, through which the low-temperature liquefied gas flows, concaved thereon are alternately stacked. The flow channels formed in these metal plates each have a flow channel width of, for example, 0.2 mm to 3 mm.

CLAIMS

1. An intermediate fluid type vaporizer comprising:
 - an intermediate fluid evaporation part that evaporates at least a part of a liquid intermediate fluid through heat exchange between a heat source medium and the intermediate fluid; and
 - a liquefied gas vaporizing part that vaporizes a low-temperature liquefied gas by condensing the intermediate fluid evaporated by the intermediate fluid evaporation part to cause a vaporized gas to flow out,wherein
 - the liquefied gas vaporizing part is configured by a stack-type heat exchanger having a stacked body which is formed with first flow channel layers each having first flow channels that are channels for flow of the intermediate fluid and second flow channel layers each having second flow channels that are channels for flow of the low-temperature liquefied gas, the stacked body having a configuration in which the first flow channel layers and the second flow channel layers being stacked, and
 - the stack-type heat exchanger is installed in a posture where the first flow channels extend in an up-and-down direction or in a direction tilted relative to the up-and-down direction so that the intermediate fluid flows down in the first flow channels due to gravity.
2. The intermediate fluid type vaporizer according to claim 1, wherein the liquefied gas vaporizing part is provided with a liquid reservoir that stores the liquid intermediate fluid on a downstream side of the first flow channels.
3. The intermediate fluid type vaporizer according to claim 2, further comprising a liquid sealing tube that connects between the liquid reservoir and a liquid level of the liquid intermediate fluid stored in the intermediate fluid evaporation part, wherein the intermediate fluid evaporation part is positioned below the liquefied gas vaporizing part.
4. The intermediate fluid type vaporizer according to any one of claims 1 to 3, wherein
 - the intermediate fluid evaporation part has a shell that stores the intermediate fluid, and
 - the liquefied gas vaporizing part is disposed within the shell of the intermediate fluid evaporation part.
5. The intermediate fluid type vaporizer according to claim 1 or 2, further comprising a circulation pipe that connects between the intermediate fluid evaporation part and the liquefied gas vaporizing part, wherein
 - the intermediate fluid evaporation part has a shell that stores the intermediate fluid,
 - the liquefied gas vaporizing part is disposed outside the shell of the

intermediate fluid evaporation part, and

the circulation pipe connects between the shell of the intermediate fluid evaporation part and the liquefied gas vaporizing part.

6. The intermediate fluid type vaporizer according to claim 1, wherein the stack-type heat exchanger is a microchannel heat exchanger.