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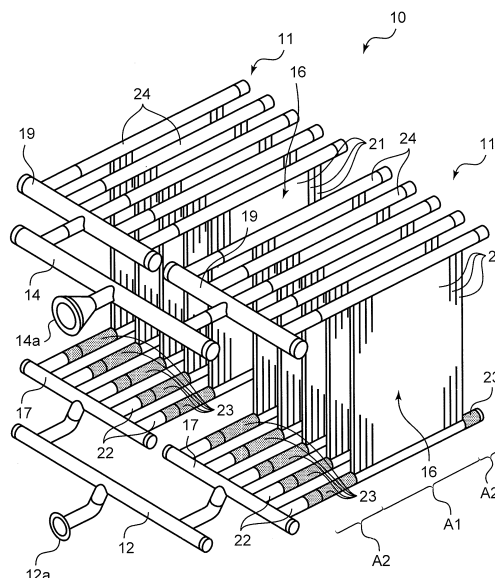
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(54) **GASIFICATION DEVICE FOR LOW-TEMPERATURE LIQUEFIED GAS**

(57) Provided is a cryogenic liquid vaporizer which allows an inter-vaporizing tube distribution pipe to become less likely to undergo bending deformation due to a difference in temperature of the inter-vaporizing tube distribution pipe in a longitudinal direction thereof. The vaporizer is characterized in that it comprises: a vaporizing tube panel (16) including a plurality of vaporizing tubes (21) and an inter-vaporizing tube distribution pipe (22) for distributing a cryogenic liquid to the respective vaporizing tubes (21), wherein the plurality of vaporizing tubes (21) are arranged on a vertical plane and side-by-side in a horizontal direction, and the inter-vaporizing tube distribution pipe (22) is disposed to extend in the horizontal direction and connected to respective lower ends of the vaporizing tubes (21); a liquid supply section (30) for supplying a heat-exchanging liquid from an upper end of the vaporizing tube panel (16) to allow the heat-exchanging liquid to flow down along the plurality of vaporizing tubes (21); and a heat-transfer suppressing section (23) for, with respect to a heat transfer rate from the heat-exchanging liquid to a first region (A1) of the inter-vaporizing tube distribution pipe (22) where the plurality of vaporizing tubes (21) are arranged, suppressing a heat transfer rate from the heat-exchanging liquid to an overall second region (A2) of the inter-vaporizing tube distribution pipe (22) located outside the first region (A1).

FIG. 1



Description

TECHNICAL FIELD

[0001] The present invention relates to a vaporizer for vaporizing a cryogenic liquid, such as liquefied natural gas (LNG), liquefied petroleum gas (LPG) or liquid nitrogen (LN₂), by means of heat exchange with a heat medium such as seawater.

BACKGROUND ART

[0002] Heretofore, there has been known a vaporizer (ORV) for vaporizing a liquefied natural gas (LNG) by means of heat exchange with seawater (heat-exchanging liquid), as disclosed in the following Patent Document 1.

[0003] As illustrated in FIG. 11, this vaporizer comprises a vaporizing tube panel 102 extending along a specific vertical plane, and a seawater supply section 104 for supplying seawater to the vaporizing tube panel 102.

[0004] The vaporizing tube panel 102 comprises a plurality of vaporizing tubes (heat transfer tubes) 106, and an inter-vaporizing tube distribution pipe (inlet-side header) 108. The seawater supply section 104 is designed to supply seawater from an upper end of the vaporizing tube panel 102 to allow the seawater to flow down along a surface of the vaporizing tube panel 102.

[0005] Each of the vaporizing tubes 106 is disposed to extend in a vertical direction to allow a liquefied natural gas (cryogenic liquid) to flow therethrough so as to cause a heat exchange with an external medium, thereby vaporizing the liquefied natural gas. The plurality of vaporizing tubes 106 comprised in the vaporizing tube panel 102 are arranged on the specific vertical plane and side-by-side in a horizontal direction to have mutually parallel postures. The inter-vaporizing tube distribution pipe 108 is designed to distribute liquefied natural gas to the respective vaporizing tubes 106 comprised in the vaporizing tube panel 102. The inter-vaporizing tube distribution pipe 108 is disposed to extend in the horizontal direction and connected to respective lower ends of the vaporizing tubes 106 comprised in the vaporizing tube panel 102.

[0006] In this type of vaporizer 100, the inter-vaporizing tube distribution pipe 108 distributes liquefied natural gas to the respective vaporizing tubes 106, and the distributed liquefied natural gas flows through each of the vaporizing tubes 106 upwardly. Concurrently, seawater supplied from the seawater supply section 104 flows down along and outside the vaporizing tubes 106. In this process, in each of the vaporizing tubes 106, heat exchange is performed between the liquefied natural gas and the seawater, through a tube wall of the vaporizing tube 106 separating an inside and an outside thereof. This allows the liquefied natural gas to be vaporized into natural gas (NG).

[0007] There has also been a vaporizer described in the following Patent Document 2. As illustrated in FIG.

12, in this vaporizer, a water protection cover 110 is disposed to cover an upper side of a first region a1 of the inter-vaporizing tube distribution pipe 108. The water protection cover 110 is designed to prevent seawater from directly hitting against the first region a1 of the inter-vaporizing tube distribution pipe 108. This makes it possible to suppress a fluctuation in heat amount of liquefied natural gas (vaporized liquefied natural gas) when the vaporizer is operated at a low load under a condition that a temperature of seawater is relatively high.

[0008] In the vaporizer disclosed in the Patent Document 1, when a cryogenic liquid (liquefied natural gas) is vaporized, a difference in temperature occurs between an end (region a2 in FIG. 11) and a central portion (region a2 in FIG. 11) of the inter-vaporizing tube distribution pipe 108 in a longitudinal direction of the distribution pipe 108. If such a temperature difference occurs, the inter-vaporizing tube distribution pipe 108 is likely to undergo bending deformation, due to a difference in amount of thermal expansion/shrinkage in each of the vaporizing tubes 106 caused by the temperature difference. This results in the occurrence of warpage in the inter-vaporizing tube distribution pipe 108, and the occurrence of stress in a joining area between the inter-vaporizing tube distribution pipe 108 and each of the vaporizing tubes 106.

[0009] Specifically, a temperature in a region located longitudinally outside a region a1 of the inter-vaporizing tube distribution pipe 108 where the plurality of vaporizing tubes 106 are arranged becomes greater than a temperature in the region a1. That is, in the inter-vaporizing tube distribution pipe 108, a temperature of a longitudinal end a2 becomes greater than a temperature of the region a1. This is based on the following reason.

[0010] When a heat-exchanging liquid (seawater) flowing down within the first region a1 along the vaporizing tube panel 102 a1 reaches the inter-vaporizing tube distribution pipe 108, it is cooled to a sufficiently low temperature by heat exchange with the cryogenic liquid in the vaporizing tubes 106. On the other hand, a heat-exchanging liquid flowing down outside the vaporizing tube panel 102 in the longitudinal direction undergoes almost no heat exchange with the cryogenic liquid in the vaporizing tubes 106. Thus, when the heat-exchanging liquid reaches the inter-vaporizing tube distribution pipe 108, it has a temperature greater than that of heat-exchanging liquid flowing down within the first region a1.

[0011] When a temperature difference occurs between the first region a1 and the second region a2 of the inter-vaporizing tube distribution pipe 108 as described above, a difference occurs between a temperature of cryogenic liquid distributed from the inter-vaporizing tube distribution pipe 108 to one of the vaporizing tubes 106 located at an endmost position of the first region a1 in the longitudinal direction, and a temperature of cryogenic liquid distributed from the inter-vaporizing tube distribution pipe 108 to one of the remaining vaporizing tubes 106 located at a centermost position of the first region a1 in the longitudinal direction. As a result, a difference in amount of

thermal expansion/shrinkage occurs between the vaporizing tube 106 at the endmost position and the vaporizing tube 106 at the centermost position, so that the inter-vaporizing tube distribution pipe 108 undergoes bending deformation.

[0012] In the vaporizer described in the Parent Document 2, the water protection cover 110 can prevent the heat-exchanging liquid from directly hitting against the first region a1 of the inter-vaporizing tube distribution pipe 108. However, in the second region a2 of the inter-vaporizing tube distribution pipe 108, the water protection cover 110 covers only a region adjacent to the vaporizing tube 106 at the endmost position, in the horizontal direction. Thus, in this vaporizer, a (relatively high-temperature) heat-exchanging liquid subjected to no heat exchange with the cryogenic liquid also hits against the second region a2 of the inter-vaporizing tube distribution pipe 108. Therefore, in this vaporizer, a temperature difference occurs between the first region a1 and the second region a2 of the inter-vaporizing tube distribution pipe 108. As a result, in the vaporizer described in the Patent Document 2, there is a concern that the inter-vaporizing tube distribution pipe 108 undergoes bending deformation, as with the vaporizer in the Patent Document 1.

LIST OF PRIOR ART DOCUMENTS

[PATENT DOCUMENTS]

[0013]

Patent Document 1: JP 57-057998A

Patent Document 2: JP 08-183970A

DISCLOSURE OF THE INVENTION

[0014] It is an object of the present invention to provide a cryogenic liquid vaporizer which allows an inter-vaporizing tube distribution pipe to become less likely to undergo bending deformation due to a difference in temperature of the inter-vaporizing tube distribution pipe in a longitudinal direction thereof.

[0015] According to one aspect of the present invention, there is provided a cryogenic liquid vaporizer for vaporizing a cryogenic liquid, which comprises:

a vaporizing tube panel including a plurality of vaporizing tubes each extending in a vertical direction and for allowing the cryogenic liquid to flow there-through so as to cause a heat exchange with an external medium, thereby vaporizing the cryogenic liquid, and an inter-vaporizing tube distribution pipe for distributing the cryogenic liquid to the respective vaporizing tubes, wherein the plurality of vaporizing tubes are arranged on a vertical plane and side-by-side in a horizontal direction, and the inter-vaporizing tube distribution pipe is disposed to extend in the horizontal direction and connected to respective low-

er ends of the vaporizing tubes; a liquid supply section for supplying a heat-exchanging liquid from an upper end of the vaporizing tube panel to allow the heat-exchanging liquid to flow down along the plurality of vaporizing tubes; and a heat-transfer suppressing section for, as compared to a heat transfer amount per unit area, from the heat-exchanging liquid to a first region of the inter-vaporizing tube distribution pipe where the plurality of vaporizing tubes are arranged, suppressing, to a same or lower level, a heat transfer amount per unit area, from the heat-exchanging liquid to a second region of the inter-vaporizing tube distribution pipe located outside the first region in the horizontal direction.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

FIG. 1 is a schematic perspective view of a cryogenic liquid vaporizer according to one embodiment of the present invention.

FIG. 2 is a schematic diagram (front view) illustrating a state of a pipe arrangement of the vaporizer.

FIG. 3 is a schematic diagram (side view) illustrating the state of the pipe arrangement of the vaporizer.

FIG. 4 is a fragmentary enlarged view for explaining a heat-transfer suppressing section of the vaporizer.

FIG. 5A is a side view for explaining a seawater supply section of the vaporizer, and FIG. 5B is a front view for explaining the seawater supply section of the vaporizer.

FIG. 6 is a partially-broken perspective view illustrating an installed state of the vaporizer.

FIG. 7 is a graph presenting a difference in temperature of liquefied natural gas flowing through an inlet-side header, depending on a thickness of a heat insulating member.

FIG. 8 is a vertical sectional view for explaining a heat insulating member (heat-transfer suppressing section) in another embodiment.

FIG. 9 is an enlarged cross-sectional view for explaining a cover member in a cryogenic liquid vaporizer according to another embodiment.

FIG. 10 is an enlarged cross-sectional view of a second region of an inter-vaporizing tube distribution pipe in a cryogenic liquid vaporizer according to another embodiment.

FIG. 11 is a fragmentary enlarged perspective view for explaining a conventional vaporizer.

FIG. 12 is a fragmentary enlarged perspective view for explaining a conventional vaporizer.

DESCRIPTION OF EMBODIMENTS

[0017] With reference to the accompanying drawings, the present invention will now be described based on one embodiment of the present invention.

[0018] A cryogenic liquid vaporizer (hereinafter also referred to simply as "vaporizer") according to this embodiment is a so-called open rack vaporizer (ORV) for subjecting a supplied cryogenic liquid to heat exchange with an external heat-exchanging liquid to thereby vaporize the cryogenic liquid. The vaporizer according to this embodiment is designed to vaporize a liquefied natural gas (LNG). The heat-exchanging liquid for use in this embodiment is seawater.

[0019] Specifically, as illustrated in FIGS. 1 to 5, the vaporizer comprises a plurality of (in this embodiment, two) vaporizing tube blocks 11, a distributing pipe 12, a collecting pipe 14, and a seawater supply section (liquid supply section) 30. The distributing pipe 12 is designed to distribute LNG to the respective vaporizing tube blocks 11. The collecting pipe 14 is designed to collect vaporized LNG (natural gas (NG)) from the vaporizing tube blocks 11. The seawater supply section 30 is designed to supply seawater to an upper portion of each of a plurality of aforementioned vaporizing tube panels 16 to allow the seawater to flow down along a surface of the vaporizing tube panel 16. The number of the vaporizing tube blocks 11 to be provided in the vaporizer 10 is not limited to two or more, but may be one.

[0020] Each of the components will be described below in detail.

[0021] Each of the vaporizing tube blocks 11 comprises a plurality of (in this embodiment, five) vaporizing tube panels 16, an inlet-side manifold 17, and an outlet-side manifold 19. The number of the vaporizing tube panels 16 to be comprised in one of the vaporizing tube blocks 11 is not limited to five, but may be any other suitable number.

[0022] Each of the vaporizing tube panels 16 comprises: a plurality of (in this embodiment, ninety) vaporizing tubes (heat transfer tubes) 21 arranged on a vertical plane and side-by-side to have mutually parallel postures; an inlet-side header (inter-vaporizing tube distribution pipe) 22; a heat-transfer suppressing section 23; and an outlet-side header 24. The number of the vaporizing tubes 21 to be comprised in one of the vaporizing tube panels 16 is not limited to ninety, but may be any other suitable number.

[0023] Each of the vaporizing tubes 21 is a tube made of a metal material having high heat conductivity, such as aluminum or an aluminum alloy, and formed to extend in an up-down direction.

[0024] The inlet-side header 22 is designed to distribute LNG from the inlet-side manifold 17 to the respective vaporizing tubes 21. Specifically, the inlet-side header 22 is a pipe extending in a horizontal direction along the vertical plane on which the vaporizing tubes 21 are arranged side-by-side. The inlet-side header 22 is made of a metal material having high heat conductivity, such as aluminum or an aluminum alloy, as with the vaporizing tubes 21. The inlet-side header 22 is connected to respective lower ends of the vaporizing tubes 21 comprised in one of the vaporizing tube panels 16. The inlet-side

header 22 is internally provided with a header inner pipe 50. The inlet-side header 22 has one end connected to the inlet-side manifold 17 to allow LNG to be supplied from the inlet-side manifold 17 via the header inner pipe 50 disposed therein.

[0025] The header inner pipe 50 is a tubular-shaped member extending along the inlet-side header 22, and is disposed inside the inlet-side header 22 in a coaxial relation to the inlet-side header 22 (see FIG. 3). The header inner pipe 50 has an outer diameter less than an inner diameter of the inlet-side header 22. Therefore, when the header inner pipe 50 is disposed inside the inlet-side header 22, a given space is defined between an outer peripheral surface of the header inner pipe 50 and an inner peripheral surface of the inlet-side header 22. The header inner pipe 50 is connected to the inlet-side manifold 17 to allow LNG to be supplied therein. The header inner pipe 50 has a plurality of holes 51 formed in a pipe wall (peripheral wall) thereof at positions corresponding to respective ones of the vaporizing tubes 21 along an axial direction of the header inner pipe 50. At each of the positions corresponding to the respective ones of the vaporizing tubes 21 along the axial direction, the hole 51 is provided in a number of two or more (in this embodiment, four). Specifically, the two or more holes 51 at the position corresponding to a respective one of the vaporizing tubes 21 along the axial direction (in this embodiment, at a position on a lower side of the vaporizing tube 21) are arranged in a circumferential direction of the header inner pipe 50 in such a manner that a center of each of the holes 51 is located in a lower half of the header inner pipe 50.

[0026] As above, the header inner pipe 50 is provided inside the inlet-side header 22 to form a double-pipe structure, and the plurality of holes 51 are provided in the header inner pipe 50 at positions corresponding to the respective vaporizing tubes 21, so that LNG is distributed to the respective vaporizing tubes 21 at an even flow rate.

[0027] In addition, the two or more holes 51 are provided in the header inner pipe 50 at the position corresponding to the respective one of the vaporizing tubes 21, so that a flow of LNG flowing into the vaporizing tube 21 becomes uniform. Specifically, when LNG flows out of the two or more holes 51 at the position corresponding to the respective one of the vaporizing tubes 21, and then flows between the inlet-side header 22 and the header inner pipe 50 toward the vaporizing tube 21, it flows upwardly in the circumferential direction of the inlet-side header 22 and then flows into the vaporizing tube 21. Thus, as compared to the case where LNG flows out of holes provided in an upper portion of the header inner pipe 50 (e.g., at positions opposed to the lower end of the vaporizing tube 21) and immediately flows into the vaporizing tube 21, a flow of LNG becomes uniform.

[0028] The heat-transfer suppressing section 23 is provided on each of opposite ends of the inlet-side header 22. The heat-transfer suppressing section 23 is designed to suppress a heat transfer amount per unit area, from

seawater to the inlet-side header 22. Specifically, the heat-transfer suppressing section 23 is configured to suppress a heat transfer amount per unit area, when heat of seawater supplied from the seawater supply section 30 is transferred to an overall (entire) second region A2 of the inlet-side header 22.

[0029] As used here, the second region A2 of the inlet-side header 22 means a region of the inlet-side header 22 which is located outside a region (first region) A1 where the plurality of vaporizing tubes 21 are arranged, in a longitudinal direction (horizontal direction) of the inlet-side header 22 (see FIGS. 3 and 4).

[0030] The first region A1 is a region of the inlet-side header 22 where the plurality of vaporizing tubes 21 are arranged in the longitudinal direction of the inlet-side header 22. That is, it is a region of the inlet-side header 22 between opposite endmost ones of the plurality of vaporizing tubes 21 arranged along the inlet-side header 22, in the longitudinal direction. On the other hand, the second region A2 is a region located outside the first region A1 in the longitudinal direction. For example, when the vaporizing tube blocks 11 are disposed within a chamber H (see FIG. 6), the second region A2 is a region of the inlet-side header 22 located inside the chamber, except the first region A1. In this case, each of the vaporizing tube blocks 11 is disposed to allow an end of the inlet-side header 22 on a side opposite to the inlet-side manifold 17 is located inside the chamber H.

[0031] More specifically, the second region A2 consists of a second sub-region A2 located on the side of the inlet-side manifold 17 (in FIG. 3, on a left side) with respect to the first region A1, and a second sub-region A2 located on a side opposite to the inlet-side manifold 17 (in FIG. 3, on a right side) with respect to the first region A1. The second sub-region A1 on the opposite side is a region ranging from an outer edge of one of the plurality of vaporizing tubes 21 disposed at a right end thereof, to a right end of the inlet-side header 22, in FIG. 4. On the other hand, the second sub-region A2 on the side of the inlet-side manifold is a region ranging from an outer edge of one of the plurality of vaporizing tubes 21 disposed at a left end thereof in FIG. 4, to a partition wall H1 of the chamber H in which the vaporizing tube blocks 11 are disposed (see FIGS. 1, 3 and 6).

[0032] The heat-transfer suppressing section 23 is a heat insulating member covering the second region A2 of the inlet-side header 22. The heat insulating member 23 has a heat conductivity less than that of the inlet-side header 22 (specifically, the pipe wall of the inlet-side header 22). The heat insulating member 23 is formed by a tape made of foamed plastic, such as urethane foam, and wound around the inlet-side header 22 to cover a surface of the second region A2. Specifically, the tape has given stretchability. The tape is overlappingly wound around the entire second region A2 of the inlet-side header 22 until a thickness thereof from the surface (outer peripheral surface) of the second region A2 of the inlet-side header 22 becomes 1.5 mm, for example. The thick-

ness of the heat insulating member 23 is appropriately set, based on a temperature difference between seawater flowing down toward the first region A1 of the inlet-side header 22 and seawater flowing down toward the second region A2 of the inlet-side header 22, the heat conductivity of the heat insulating member 23 and so on.

[0033] In the inlet-side header 22, the heat insulating member 23 is provided on only the second region A2, but it is not provided on the first region A1. That is, the first region A1 of the inlet-side header 22 is in an externally exposed state, and the second region A2 is in a state in which it is entirely covered by the heat insulating member 23.

[0034] In this way, the heat insulating member 23 is provided on the second region A2 of the inlet-side header 22, so that a heat transfer rate from seawater (specifically, seawater supplied from the seawater supply section 30) to the second region A2 of the inlet-side header 22 is suppressed as compared with a heat transfer rate from the seawater to the first region A1 of the inlet-side header 22. This allows a temperature of the pipe wall of the second region A2 of the inlet-side header 22 to be kept from becoming greater than a temperature of the pipe wall of the first region A1 of the inlet-side header 22, even if seawater flowing down toward the second region of the inlet-side header 22 has a temperature greater than of seawater flowing down from the seawater supply section 30 toward the first region A1 of the inlet-side header 22.

[0035] In addition, the heat insulating member 23 has given stretchability because it is formed by the tape having stretchability. Thus, even when the inlet-side header 22 thermally expands or shrinks, the heat insulating member 23 itself expands or shrinks according to the thermal expansion/shrinkage. This makes it possible to effectively prevent damage, such as breakage of the heat insulating member 23 due to thermal expansion/shrinkage of the inlet-side header 22 (particularly, thermal expansion/shrinkage of the inlet-side header 22 in a radial direction thereof).

[0036] The outlet-side header 24 is designed to collect vaporized LNG from the vaporizing tubes 21 and send it to the outlet-side manifold 19. The outlet-side header 24 is a pipe extending parallel to the inlet-side header 22. The outlet-side header 24 is connected to the vaporizing tubes 21 comprised in one of the vaporizing tube panels 16, and connected to the outlet-side manifold 19.

[0037] The plurality of vaporizing tube panels 16 each configured in the above manner are arranged in a direction (in FIG. 2, a right-left direction) orthogonal to a panel plane (the vertical plane on which the vaporizing tubes 21 are arranged) to have mutually parallel postures.

[0038] The inlet-side manifold 17 is designed to distribute LNG from the distributing pipe 12, to the respective vaporizing tube panels 16. The inlet-side manifold 17 is a pipe extending in a direction intersecting with the inlet-side header 22 (in this embodiment, a direction approximately orthogonal to the inlet-side header 22; a direction perpendicular to a drawing sheet in FIG. 3). The inlet-

side manifold 17 is connected to the respective inlet-side headers 22 comprised in one of the vaporizing tube blocks 11, and is connected to the distributing pipe 12.

[0039] The outlet-side manifold 19 is designed to collect vaporized LNG (i.e., NG) from the vaporizing tube panels 16 and send it to the collecting pipe 14. The outlet-side manifold 19 is a pipe extending in a direction intersecting with the outlet-side header 24 (in this embodiment, a direction approximately orthogonal to the outlet-side header 24: a direction perpendicular to a drawing sheet in FIG. 3). The outlet-side manifold 19 is connected to the respective outlet-side headers 24 comprised in one of the vaporizing tube blocks 11, and is connected to the collecting pipe 14.

[0040] The distributing pipe 12 is a pipe extending approximately parallel to the inlet-side manifold 17. The distributing pipe 12 is connected to the respective inlet-side manifolds 17. The distributing pipe 12 has an inlet-side connection portion 12a to which a pipe P1 is connected to supply LNG to the vaporizer 10 from the outside.

[0041] The collection pipe 14 is a pipe extending approximately parallel to the outlet-side manifold 19. The collection pipe 14 is connected to the respective outlet-side manifolds 19. The collecting pipe 14 has an outlet-side connection portion 14a to which a pipe P2 is connected to send NG to the outside, such as a destination for consumption.

[0042] The seawater supply section 30 comprises a trough 31, a seawater header 32 and a seawater manifold 33 (see FIGs. 5A and 5B). The trough 31 is disposed adjacent to an upper end of each of the vaporizing tube panels 16. The trough 31 is configured to supplying seawater to the upper end of each of the vaporizing tube panels 16 to allow the seawater to flow down along the surface of the vaporizing tube panel 16 (specifically, the vaporizing tubes 21 constituting the corresponding vaporizing tube panel 16). Seawater (medium outside of the vaporizing tubes 21) supplied from the trough 31 to flow down along the surface of the vaporizing tube panel 16, and LNG flowing inside of the vaporizing tubes 21, are heat-exchanged through respective tube walls of the vaporizing tubes 21. Consequently, LNG is vaporized into NG. The seawater header 32 is configured to supply seawater to each of a plurality of the troughs 31. The seawater manifold 33 is configured to distribute seawater to a plurality of the seawater headers 32.

[0043] The vaporizing tube blocks 11 of the vaporizer 10 configured as above are disposed inside the chamber H surrounded by a wall such as a concrete wall, as illustrated in FIG. 6. Specifically, each of the vaporizing tube blocks 11 is disposed inside the chamber H in such a manner that the inlet-side manifold 17 and the outlet-side manifold 19 of the vaporizing tube block 11 are located outside the chamber H. The chamber H has a partition H1 separating between an inside and outside of the chamber at a position between the set of vaporizing tubes 21 and the inlet-side manifold 17 in the longitudinal direction of the inlet-side header 22. The inlet-side header

22 penetrates through the partition wall H1 at a position between an end thereof (on the side of the inlet-side manifold 17) and one of the vaporizing tubes 21 located on the side of the end of the inlet-side header 22, and the outlet-side header 24 penetrates through the partition wall H1 at a position between an end thereof (on the side of the outlet-side manifold 19) and one of the vaporizing tubes 21 located on the side of the end of the outlet-side header 24. A heat insulating member is provided to entirely cover a surface of each of the pipes 12, 14, 17, 19 disposed outside the chamber H.

[0044] The vaporizer 10 configured as above is operable to vaporize LNG in the following manner.

[0045] Seawater is supplied from the troughs 31 to respective surfaces of the vaporizing tube panels 16. Concurrently, LNG is supplied from a supply pump or the like to the distributing pipe 12 via the pipe P1 connected to the inlet-side connection portion 12a. The distributing pipe 12 distributes LNG supplied from the supply pump or the like, to each of the inlet-side manifolds 17 connected to the distributing pipe 12. Each of the inlet-side manifolds 17 distributes LNG from the distributing pipe 12, to the respective inlet-side headers 22 connected to the inlet-side manifold 17. Each of the inlet-side headers 22 distributes the supplied LNG to the respective vaporizing tubes 21 connected to the inlet-side header 22. The LNG supplied from the inlet-side header 22 flows inside of each of the vaporizing tubes 21 in a direction from the lower end to upper end of the vaporizing tube 21. In this process, the LNG flowing through the vaporizing tube 21 undergoes heat exchange with seawater flowing down along a surface of the vaporizing tube 21, through the tube wall of the vaporizing tube 21. Based on this heat exchange, the LNG is vaporized into NG.

[0046] When the vaporization of LNG is being performed in the vaporizer 10, the seawater supply section 30 supplies seawater to not only a primary region where the vaporizing tubes 21 of the vaporizing tube panel 16 are provided, but also a region outside the primary region in a width direction (an arrangement direction of the vaporizing tubes 21 in the vaporizing tube panels 16). This is intended to allow each of the vaporizing tubes 21 located at opposite endmost positions in the width direction to sufficiently contact seawater in the entire circumference of the vaporizing tubes 21. Thus, when LNG is vaporized into NG, i.e., during operation of the vaporizer 10, seawater flows down along the vaporizing tube panel 16 toward the first region A1 of the inlet-side header 22, and reaches the inlet-side header 22, it is cooled to a sufficiently low temperature by heat exchange with LNG in the vaporizing tubes 21. On the other hand, seawater flowing down outside the vaporizing tubes 21 (i.e., flowing down toward the second region A2 of the inlet-side header 22) undergoes almost no heat exchange with LNG in the vaporizing tubes 21, so that a temperature of the seawater reaching the inlet-side header 22 is greater than that of water flowing down toward the first region A1. Thus, supposing that the heat insulating member (heat-

transfer suppressing section) 23 is not provided on the second region A2 of the inlet-side header 22, the pipe wall in the second region A2 of the inlet-side header 22 has a temperature greater than that of the pipe wall in the first region A1 of the inlet-side header 22 subjected to the heat exchange with water. Therefore, LNG supplied to the vaporizing tube 21 adjacent to the second region A2 (vaporizing tubes 21 at an endmost position in the width direction of the vaporizing tube panel) (specifically, LNG flowing upwardly along the circumferential direction of the inlet-side header 22 when it flowing out of the holes 51 of the header inner pipe 50 and then flowing between the header inner pipe 50 and the inlet-side header 22 toward the vaporizing tube 21) has a temperature greater than that of LNG supplied to the vaporizing tube 21 at a centermost position of the first region A1. However, in the vaporizer 10 according to this embodiment, the heat insulating member 23 is provided on the second region A2 of the inlet-side header 22, so that a heat transfer amount per unit area, from the relatively high-temperature seawater to the pipe wall in the second region A2, is suppressed. This prevents the occurrence of a temperature difference between LNG supplied to the vaporizing tube 21 adjacent to the second region A2 of the inlet-side header 22, and LNG supplied to the vaporizing tube 21 at a centermost position of the first region A1 of the inlet-side header 22.

[0047] Vaporized LNG, i.e., NG, from the vaporizing tubes 21, is collected by the outlet-side header 24, and sent to the outlet-side manifold 19. The NG sent to the outlet-side manifold 19 is sent to a destination for consumption or the like, via the collecting pipe 14, and the pipe P2 connected to the outlet-side connection portion 14a.

[0048] As above, in the vaporizer 10, even in a situation where seawater flowing down toward the second region A2 of the inlet-side header 22 has a temperature greater than that of seawater flowing down toward the first region A1 of the inlet-side header 22, the heat insulating member (heat-transfer suppressing section) 23 functions to suppress a heat transfer amount per unit area, from seawater to the overall second region A2 of the inlet-side header 22 (a region of the inlet-side header 22 inside the chamber H housing the vaporizing tube blocks 11, except the first region A1). Thus, it becomes possible to prevent a temperature in the second region A2 of the inlet-side header 22 from becoming greater than that in the first region A1 of the inlet-side header 22. This makes it possible to suppress a temperature difference between LNG distributed to the vaporizing tube 21 at an endmost position of the vaporizing tube panel 16 in the horizontal direction (width direction) thereof, and LNG distributed to the vaporizing tube 21 at a centermost position of the first region A1 in the horizontal direction. As a result, it becomes possible to prevent bending deformation of the inlet-side header 22 due to amounts of thermal expansion/shrinkage in the vaporizing tubes 21.

[0049] In the vaporizer 10 according to this embodi-

ment, the overall (entire) second region A2 of the inlet-side header 22 is surrounded by the heat insulating member 23. This makes it possible to suppress a heat transfer amount per unit area from seawater to the second region A2 of the inlet-side header 22, as compared to a heat transfer amount per unit area from seawater to the first region A1 of the inlet-side header 22, in an easy and reliable manner.

[0050] In the vaporizer 10 according to this embodiment, the heat insulating member 23 has given stretchability, so that it becomes possible to prevent damage of the heat insulating member 23 due to thermal expansion/shrinkage of the inlet-side header 22. Specifically, the inlet-side header 22 thermally expands or shrinks due to a temperature difference between during operation of the vaporizer 10 and during stopping of the vaporizer 10. In this situation, the heat insulating member 23 surrounding the inlet-side header 22 has given stretchability, so that it can stretch or contract according to thermal expansion/shrinkage of the inlet-side header 22. This makes it possible to effectively prevent damage of the heat insulating member 23 due to thermal expansion/shrinkage (particularly, thermal expansion/shrinkage in the radial direction) of the inlet-side header 22.

EXAMPLE 1

[0051] In order to ascertain effects of the heat insulating member, by using a vaporizer having the same configuration as that of the vaporizer 10, except the heat insulating member 23, a temperature of LNG flowing in the second region of the inlet-side header 22 during operation of the vaporizer was checked

[0052] An inlet-side header of this vaporizer is made of aluminum and formed to have an outer diameter of 165.2 mm. The inlet-side header has a heat transfer rate of 5000 W/mK. The heat insulating member has a heat conductivity of 1 W/mK.

[0053] A temperature of LNG flowing the second region of the above inlet-side header was measured while supplying LNG having a temperature of -145°C, to the inlet-side header, under the following three conditions: without any heat insulating member; with a heat insulating member having a thickness of 0.5 mm; and with a heat insulating member having a thickness of 1.5 mm. A result of the measurement is illustrated in FIG. 7.

[0054] The graph in FIG. 7 shows that a temperature rise of LNG flowing through the inlet-side header due to seawater can be suppressed by providing a heat insulating member on the second region of the inlet-side header even if the heat insulating member has a relatively small thickness, as compared to the case without any heat insulating member.

[0055] Based on this result, it was verified that a temperature difference between the first region and the second region in the inlet-side header can be suppressed by providing a heat insulating member on the second region, even in the situation where seawater flowing

down toward the second region has a temperature greater than that of seawater flowing down toward the first region.

[0056] The cryogenic liquid vaporizer of the present invention is not limited to the above embodiment, but it is to be understood that various changes and modifications may be made therein without departing from the spirit and scope thereof as set forth in appended claims

[0057] A specific configuration of the heat insulating member 23 is not particularly limited. For example, although the heat insulating member 23 in the above embodiment is formed by overlappingly winding (wrapping) a tape made of foamed plastic such as urethane foam, around the second region A2 of the inlet-side header 22, it is not limited thereto. That is, as illustrated in FIG. 8, the heat insulating member may be tubular and bottomed tubular-shaped members 23A, 23B each made of a material having relatively small heat conductivity (e.g., resin such as silicon resin or polyvinyl chloride resin; foamed resin; or resin incorporating glass fiber or rubber). Each of the tubular-shaped heat insulating member 23A and the bottomed tubular-shaped heat insulating member 23B has an inner peripheral surface 123 with a diameter (inner diameter) corresponding to a diameter (outer diameter) of an outer peripheral surface of the second region A2 of the inlet-side header 22, or with an inner diameter greater than the outer diameter. The tubular-shaped heat insulating member 23A is fit on the second sub-region A2 of the inlet-side header 22 on the side of the inlet-side manifold 17. On the other hand, the bottomed tubular-shaped heat insulating member 23B is fit on the second sub-region A2 of the inlet-side header 22 on a side opposite to the inlet-side manifold 17. In this manner, the overall second region A2 is surrounded by the insulating members 23A, 23B.

[0058] Alternatively, the heat insulating member may be formed by foamed plastic, such as urethane foam, sprayed onto the surface of the second region A2 of the inlet-side header 22 to have a given thickness.

[0059] The heat-transfer suppressing section is not limited to the configuration surrounding the second region A2 of the inlet-side header 22. For example, the heat-transfer suppressing section may be a cover member 60 (see FIG. 9) disposed on an upper side of the second region A2 of the inlet-side header 22, and formed in a shape capable of covering over the second region A2 of the inlet-side header 22, in top plan view. This cover member 60 has a width (in a horizontal direction) greater than the outer diameter of the inlet-side header 22 so as to cover over the second region A2 of the inlet-side header 22, in top plan view. Further, the cover member 60 is disposed on the upper side of the second region A2 of the inlet-side header 22, in spaced-apart relation to (or in contact with) the second region A2. The above configuration can prevent seawater flowing down outside the vaporizing tube at the endmost position in the longitudinal direction of the inlet-side header (horizontal direction) and undergoing almost no heat exchange with LNG flow-

ing through the vaporizing tube, from hitting against the second region of the inlet-side header. This makes it possible to prevent the occurrence of a temperature difference between the first region A1 and the second region A2 in the inlet-side header 22, even in the situation where seawater flowing down toward the second region A2 of the inlet-side header 22 has a temperature greater than that of seawater flowing down toward the first region A1 of the inlet-side header 22. That is, the cover member 60 is provided to prevent seawater falling down from the seawater supply section 30 from hitting against the second region A2 of the inlet-side header 22, so that it becomes possible to allow heat to become less likely to be transferred from the seawater to inside the second region A2 of the inlet-side header 22. In this manner, a temperature difference between LNG flowing through the first region A1 and LNG flowing through the second region A2 of the inlet-side header 22 may be suppressed.

[0060] Alternatively, the pipe wall of the second region A2 of the inlet-side header may be made of a material having a heat conductivity less than that of the pipe wall of the first region A1 of the inlet-side header. Specifically, for example, the pipe wall of the first region A1 may be made of a metal material having high heat conductivity, such as aluminum or an aluminum alloy, as with the first embodiment, and the pipe wall of the second region A2 may be made of iron or SUS. As a result, the heat conductivity in the pipe wall of the second region A2 of the inlet-side header becomes less than that in the pipe wall of the first region A1 of the inlet-side header. Thus, even when seawater having a temperature greater than that in the first region A1 hits against the second region A2, it becomes possible to prevent the occurrence of a temperature difference between LNG flowing through the first region A1 of the inlet-side header and LNG flowing through the second region A2 of the inlet-side header. This makes it possible to prevent bending deformation of the inlet-side header due to the above temperature difference.

[0061] Further, only the pipe wall in the second region A2 of the inlet-side header 22 may be formed in a layered structure in a thickness direction of the pipe wall. This configuration can suppress heat conductivity in a direction from a surface (outer peripheral surface) of the second region A2 of the inlet-side header to an inside of the second region A2 (inner peripheral surface of the inlet-side header), so that a heat conductivity (equivalent heat conductivity) of the pipe wall of the second region A2 of the inlet-side header 22 becomes less than that of the pipe wall of the first region A1 of the inlet-side header 22. Specifically, as illustrated in FIG. 10, the pipe wall of the second region A2 of the inlet-side header 22 is composed of a plurality of layers (in the embodiments illustrated in FIG. 10, two layers), and a heat-transfer suppressing layer 62 filled with air or a heat insulating material is formed between the layers. In this configuration, a heat conductivity (equivalent heat conductivity) in the pipe wall of the second region A2 of the inlet-side header 22 becomes

less than that in the pipe wall of the first region A1 of the inlet-side header 22. The number of layers constituting the pipe wall may be three or more.

[0062] In the above embodiment, the header inner pipe 50 is provided inside the inlet-side header 22. However, the vaporizer is not limited to this configuration. That is, the vaporizer may be configured to allow LNG to be directly supplied from the inlet-side manifold 17 to the inlet-side header 22, without providing the header inner pipe 50.

[OUTLINE OF EMBODIMENTS]

[0063] The above embodiments can be outlined as follows.

[0064] The above embodiments relate to a cryogenic liquid vaporizer for vaporizing a cryogenic liquid. The cryogenic liquid vaporizer comprises: a vaporizing tube panel including a plurality of vaporizing tubes each extending in a vertical direction and for allowing the cryogenic liquid to flow therethrough so as to cause a heat exchange with an external medium, thereby vaporizing the cryogenic liquid, and an inter-vaporizing tube distribution pipe for distributing the cryogenic liquid to the respective vaporizing tubes, wherein the plurality of vaporizing tubes are arranged on a vertical plane and side-by-side in a horizontal direction, and the inter-vaporizing tube distribution pipe is disposed to extend in the horizontal direction and connected to respective lower ends of the vaporizing tubes; a liquid supply section for supplying a heat-exchanging liquid from an upper end of the vaporizing tube panel to allow the heat-exchanging liquid to flow down along the plurality of vaporizing tubes; and a heat-transfer suppressing section for, as compared to a heat transfer amount per unit area, from the heat-exchanging liquid to a first region of the inter-vaporizing tube distribution pipe where the plurality of vaporizing tubes are arranged, suppressing, to a same or lower level, a heat transfer amount per unit area, from the heat-exchanging liquid to a second region of the inter-vaporizing tube distribution pipe located outside the first region in the horizontal direction. As used here, the term "same or lower level" of heat transfer amount encompasses a situation where a temperature of the heat-exchanging liquid flowing through the second region of the inter-vaporizing tube distribution pipe, when heat is transferred from the heat-exchanging liquid to the cryogenic liquid flowing through the inter-vaporizing tube distribution pipe, is equal or less than a temperature of the heat-exchanging liquid flowing through the first region of the inter-vaporizing tube distribution pipe, but also a situation where the temperature of the heat-exchanging liquid flowing through the second region is slightly greater than the temperature of the heat-exchanging liquid flowing through the first region, to an extent of exerting no influence on bending deformation of the inter-vaporizing tube distribution pipe.

[0065] In the vaporizer, even in a situation where the heat-exchanging liquid flowing down toward the second

region of the inter-vaporizing tube distribution pipe has a temperature greater than that of the heat-exchanging liquid flowing down toward the first region of the inter-vaporizing tube distribution pipe, the heat-transfer suppressing section functions to suppress a heat transfer amount per unit area, from the heat-exchanging liquid to the second region. Thus, it becomes possible to prevent a temperature in the second region of the inter-vaporizing tube distribution pipe from becoming greater than that in the first region of the inter-vaporizing tube distribution pipe. This makes it possible to suppress a temperature difference between the cryogenic liquid distributed from the inter-vaporizing tube distribution pipe to the vaporizing tube at an endmost position of the vaporizing tube panel in the horizontal direction thereof, and LNG distributed from the inter-vaporizing tube distribution pipe to the vaporizing tube at a centermost position of the first region, so that it becomes possible to prevent bending deformation of the inter-vaporizing tube distribution pipe due to amounts of thermal expansion/shrinkage in the vaporizing tubes.

[0066] In the cryogenic liquid vaporizer according to the above embodiments, the heat-transfer suppressing section is a heat insulating member surrounding the second region of the inter-vaporizing tube distribution pipe, wherein the heat insulating member has a heat conductivity less than a heat conductivity of the inter-vaporizing tube distribution pipe.

[0067] This configuration makes it possible to suppress a heat transfer amount per unit area from the heat-exchanging liquid to the second region of the inter-vaporizing tube distribution pipe, as compared to a heat transfer amount per unit area from the heat-exchanging liquid to the first region of the inter-vaporizing tube distribution pipe, in an easy and reliable manner.

[0068] In this case, it is preferable that the heat insulating member has given stretchability.

[0069] This configuration makes it possible to prevent damage of the heat insulating member due to thermal expansion/shrinkage of the inter-vaporizing tube distribution pipe. Specifically, the heat insulating member surrounding the inter-vaporizing tube distribution pipe has given stretchability. Thus, when the inter-vaporizing tube distribution pipe thermally expands or shrinks due to a temperature difference between when the cryogenic liquid is flowing (i.e., during operation of the vaporizer) and when the cryogenic liquid is not flowing (i.e., during stopping of the vaporizer), the heat insulating member can stretch or contract according to thermal expansion/shrinkage of the inter-vaporizing tube distribution pipe. This makes it possible to effectively prevent damage of the heat insulating member due to thermal expansion/shrinkage (particularly, thermal expansion/shrinkage in a radial direction) of the inter-vaporizing tube distribution pipe.

[0070] The heat-transfer suppressing section may be a cover member which is disposed on an upper side of the second region of the inter-vaporizing tube distribution

pipe, and formed in a shape capable of covering over the second region of the inter-vaporizing tube distribution pipe, in top plan view.

[0071] This configuration can prevent the heat-exchanging liquid flowing down outside the vaporizing tube at the endmost position in a longitudinal direction of the inter-vaporizing tube distribution pipe (horizontal direction) and undergoing almost no heat exchange with the cryogenic liquid flowing through the vaporizing tube, from hitting against the second region of the inter-vaporizing tube distribution pipe. This makes it possible to prevent the occurrence of a temperature difference between the first region and the second region in the inter-vaporizing tube distribution pipe.

[0072] When a portion of the inter-vaporizing tube distribution pipe between one end thereof and one of the vaporizing tubes located on the side of the one end is disposed to penetrate through a partition wall, the second region is a region between the partition wall and the vaporizing tube located on the side of the one end.

[0073] In order to solve the above problems, the present invention provides a cryogenic liquid vaporizer for vaporizing a cryogenic liquid. The cryogenic liquid vaporizer comprises: a vaporizing tube panel including a plurality of vaporizing tubes each extending in a vertical direction and for allowing the cryogenic liquid to flow therethrough so as to cause a heat exchange with an external medium, thereby vaporizing the cryogenic liquid, and an inter-vaporizing tube distribution pipe for distributing the cryogenic liquid to the respective vaporizing tubes, wherein the plurality of vaporizing tubes are arranged on a specific vertical plane and side-by-side in a horizontal direction, and the inter-vaporizing tube distribution pipe is disposed to extend in the horizontal direction and connected to respective lower ends of the vaporizing tubes; and a liquid supply section for supplying a heat-exchanging liquid from an upper end of the vaporizing tube panel to allow the heat-exchanging liquid to flow down along the plurality of vaporizing tubes. In the cryogenic liquid vaporizer, with respect to a heat conductivity of a pipe wall in a first region of the inter-vaporizing tube distribution pipe where the plurality of vaporizing tubes are arranged, a heat conductivity of a pipe wall in a second region of the inter-vaporizing tube distribution pipe located outside the first region in the horizontal direction has a smaller value.

[0074] In this configuration, the heat conductivity of the pipe wall in the second region of the inter-vaporizing tube distribution pipe is less than that of the pipe wall in the first region of the inter-vaporizing tube distribution pipe, so that, even when a heat-exchanging liquid having a temperature greater than that of the first region of the inter-vaporizing tube distribution pipe hits against the second region of the inter-vaporizing tube distribution pipe, it becomes possible to prevent the occurrence of a temperature difference between the cryogenic liquid flowing through the first region of the inter-vaporizing tube distribution pipe, and the cryogenic liquid flowing through

the second region of the inter-vaporizing tube distribution pipe. This makes it possible to prevent bending deformation of the inter-vaporizing tube distribution pipe due to the above temperature difference.

INDUSTRIAL APPLICABILITY

[0075] As above, the cryogenic liquid vaporizer of the present invention is useful for vaporizing a cryogenic liquid, such as liquefied natural gas (LNG), liquefied petroleum gas (LPG) or liquid nitrogen (LN₂), by means of heat exchange with a heat medium such as seawater, and suited to suppress bending deformation due to a difference in temperature of the inter-vaporizing tube distribution pipe in a longitudinal direction thereof.

Claims

1. A cryogenic liquid vaporizer for vaporizing a cryogenic liquid, comprising:

a vaporizing tube panel including a plurality of vaporizing tubes each extending in a vertical direction and for allowing the cryogenic liquid to flow therethrough so as to cause a heat exchange with an external medium, thereby vaporizing the cryogenic liquid, and an inter-vaporizing tube distribution pipe for distributing the cryogenic liquid to the respective vaporizing tubes, wherein the plurality of vaporizing tubes are arranged on a vertical plane and side-by-side in a horizontal direction, and the inter-vaporizing tube distribution pipe is disposed to extend in the horizontal direction and connected to respective lower ends of the vaporizing tubes; a liquid supply section for supplying a heat-exchanging liquid from an upper end of the vaporizing tube panel to allow the heat-exchanging liquid to flow down along the plurality of vaporizing tubes; and

a heat-transfer suppressing section for, as compared to a heat transfer amount per unit area, from the heat-exchanging liquid to a first region of the inter-vaporizing tube distribution pipe where the plurality of vaporizing tubes are arranged, suppressing, to a same or lower level, a heat transfer amount per unit area, from the heat-exchanging liquid to a second region of the inter-vaporizing tube distribution pipe located outside the first region in the horizontal direction.

2. The cryogenic liquid vaporizer as defined in claim 1, wherein the heat-transfer suppressing section is a heat insulating member surrounding the second region of the inter-vaporizing tube distribution pipe, the heat insulating member having a heat conductivity less than a heat conductivity of the inter-vaporizing

tube distribution pipe.

3. The cryogenic liquid vaporizer as defined in claim 2, wherein the heat insulating member has given stretchability. 5

4. The cryogenic liquid vaporizer as defined in claim 1, wherein the heat-transfer suppressing section is a cover member which is disposed on an upper side of the second region of the inter-vaporizing tube distribution pipe, and formed in a shape capable of covering over the second region of the inter-vaporizing tube distribution pipe, in top plan view. 10

5. The cryogenic liquid vaporizer as defined in any one of claims 1 to 4, wherein a portion of the inter-vaporizing tube distribution pipe between one end thereof and one of the vaporizing tubes located on the side of the one end is disposed to penetrate through a partition wall, wherein the second region is a region between the partition wall and the vaporizing tube located on the side of the one end. 15 20

6. A cryogenic liquid vaporizer for vaporizing a cryogenic liquid, comprising: 25
 - a vaporizing tube panel including a plurality of vaporizing tubes each extending in a vertical direction and for allowing the cryogenic liquid to flow therethrough so as to cause a heat exchange with an external medium, thereby vaporizing the cryogenic liquid, and an inter-vaporizing tube distribution pipe for distributing the cryogenic liquid to the respective vaporizing tubes, wherein the plurality of vaporizing tubes are arranged on a specific vertical plane and side-by-side in a horizontal direction, and the inter-vaporizing tube distribution pipe is disposed to extend in the horizontal direction and connected to respective lower ends of the vaporizing tubes; and 30 35 40
 - a liquid supply section for supplying a heat-exchanging liquid from an upper end of the vaporizing tube panel to allow the heat-exchanging liquid to flow down along the plurality of vaporizing tubes, 45
 - wherein, with respect to a heat conductivity of a pipe wall in a first region of the inter-vaporizing tube distribution pipe where the plurality of vaporizing tubes are arranged, a heat conductivity of a pipe wall in a second region of the inter-vaporizing tube distribution pipe located outside the first region in the horizontal direction has a smaller value. 50 55

FIG. 1

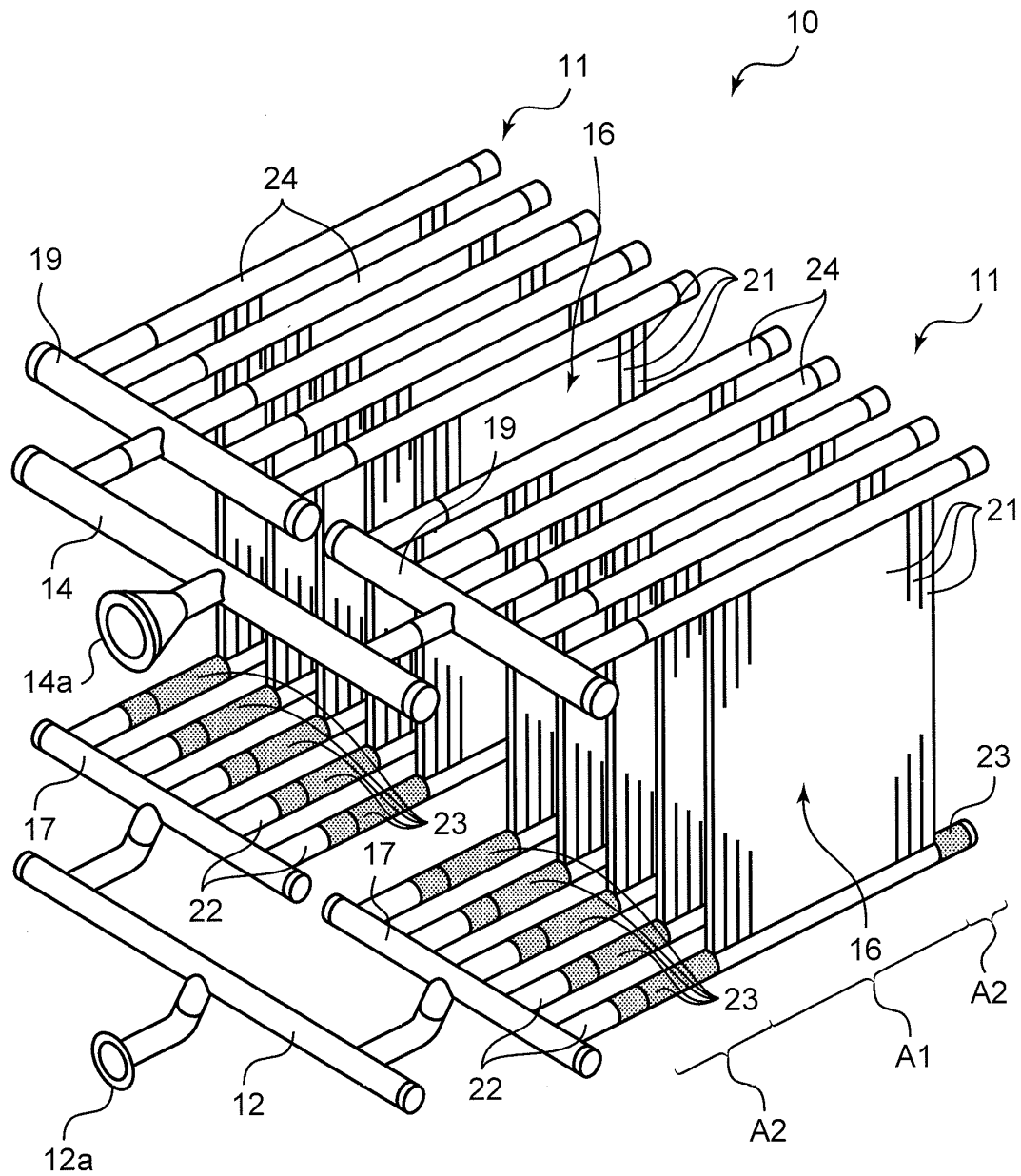
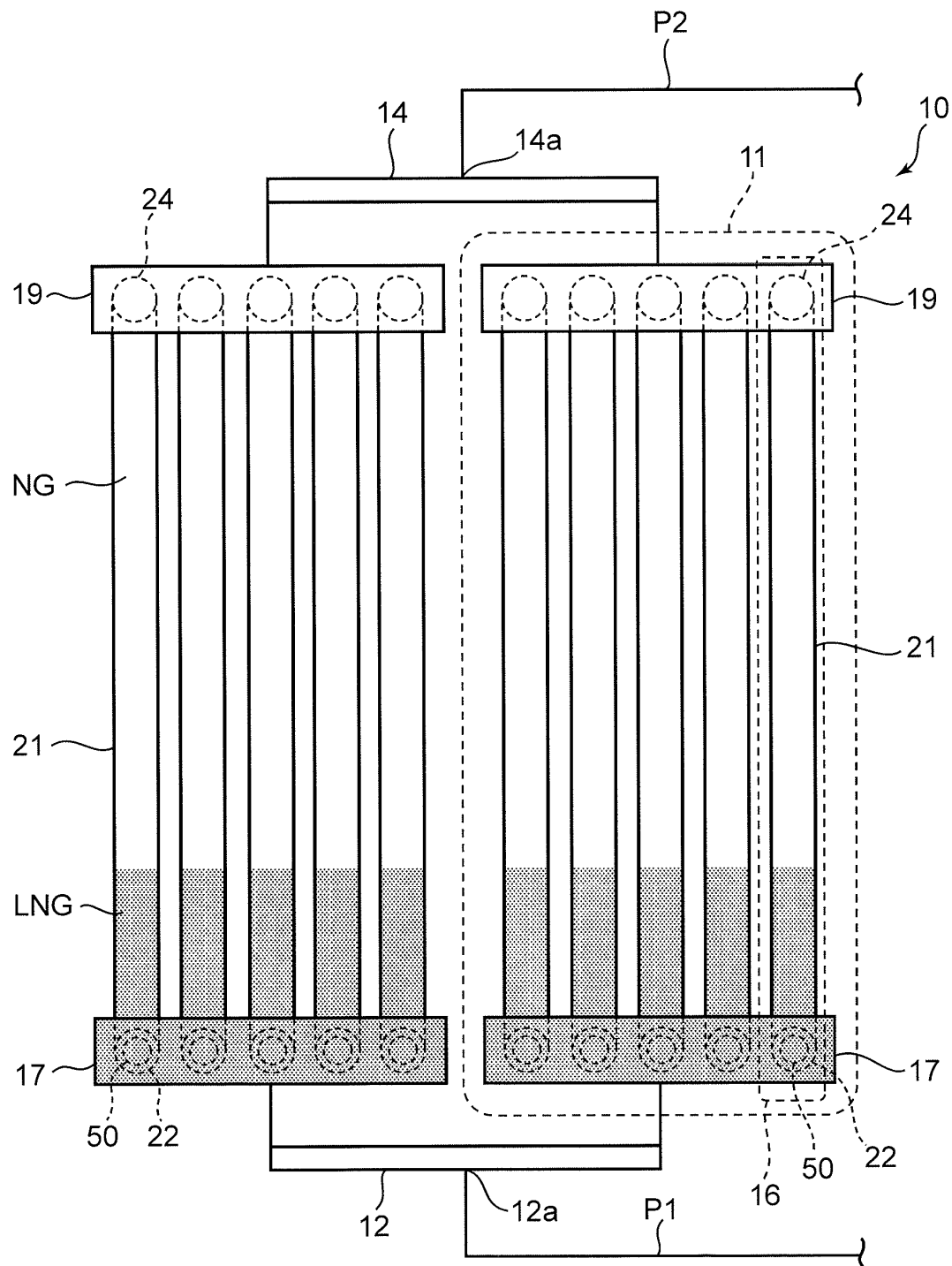


FIG. 2



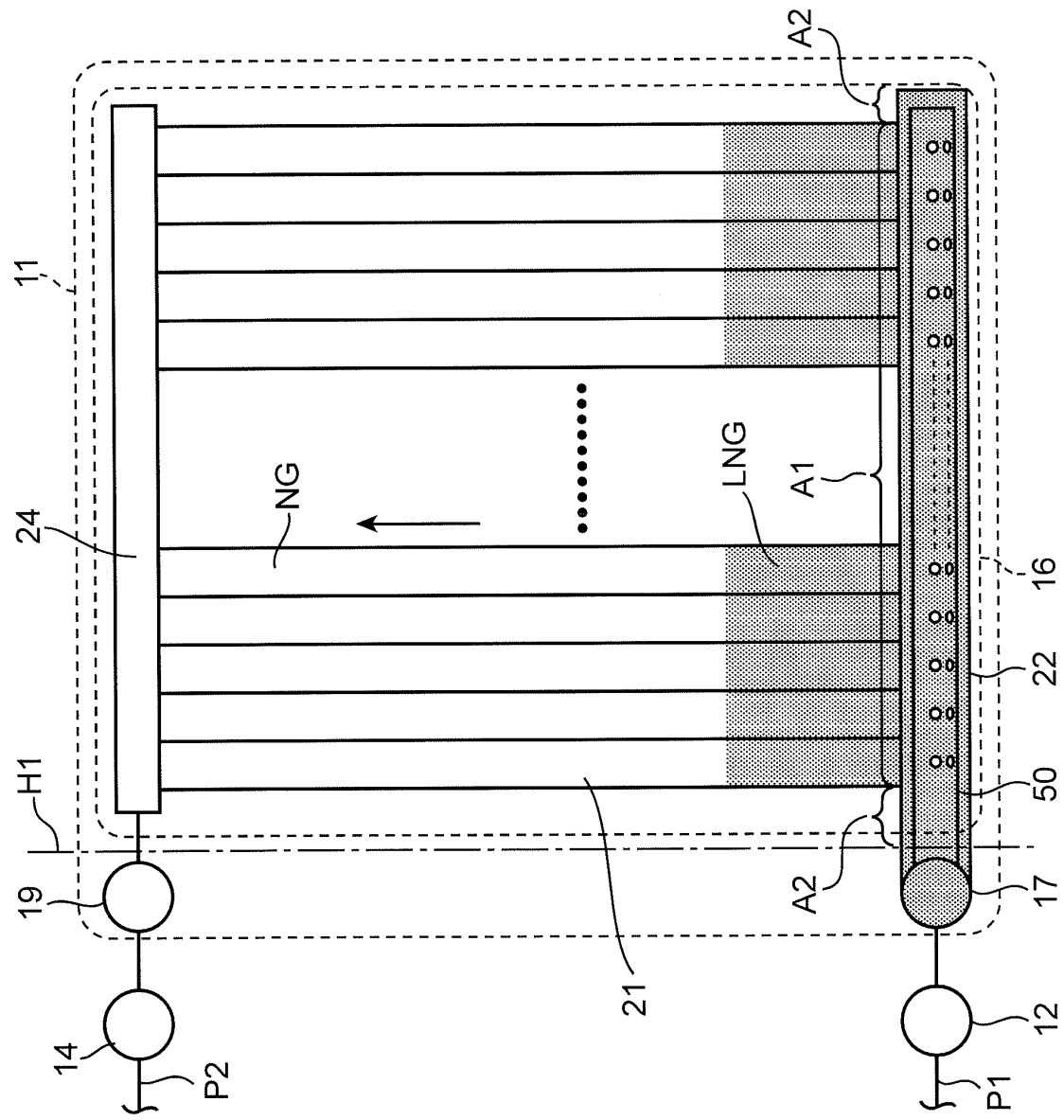


FIG. 3

FIG. 4

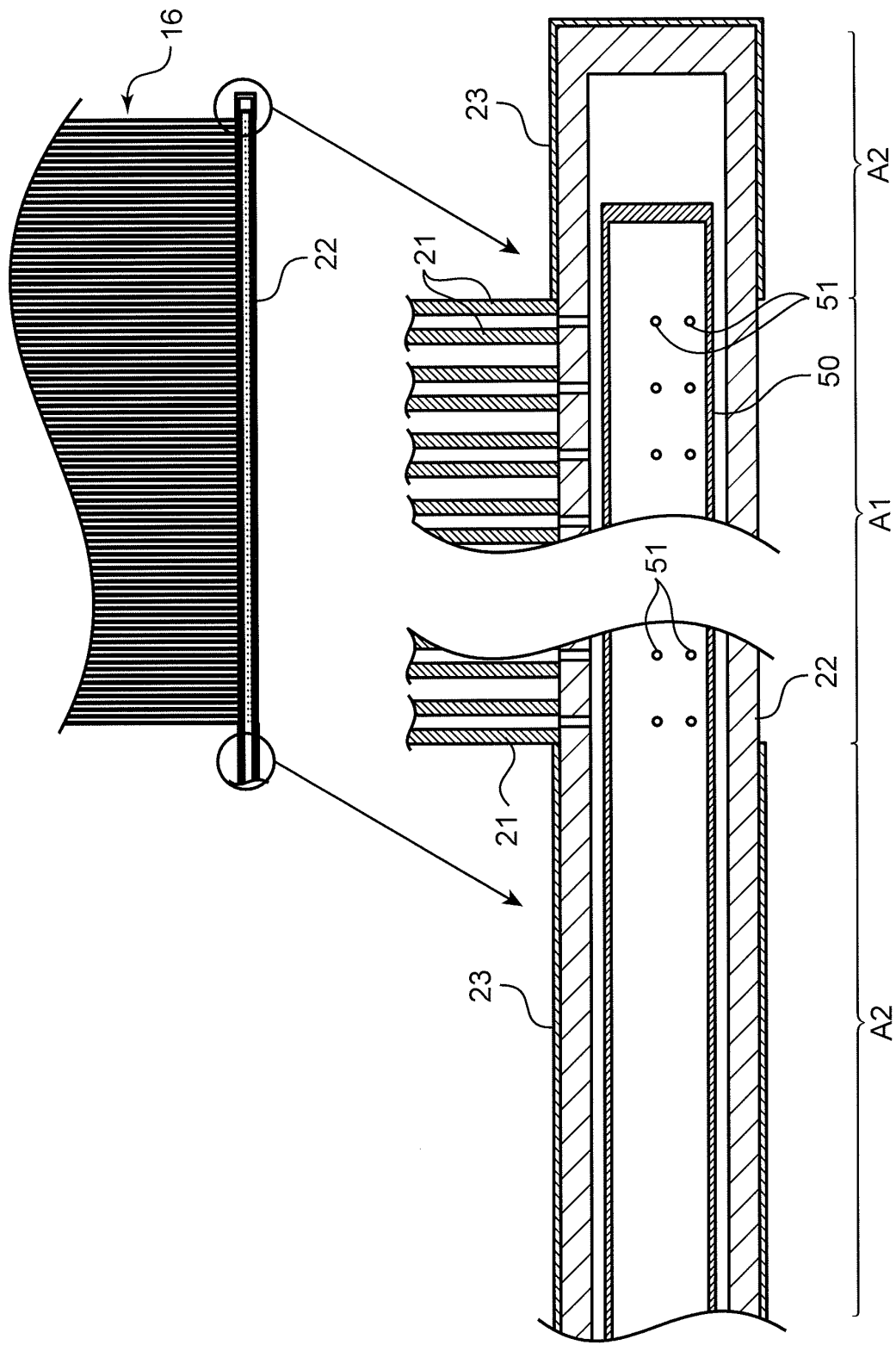


FIG. 5A

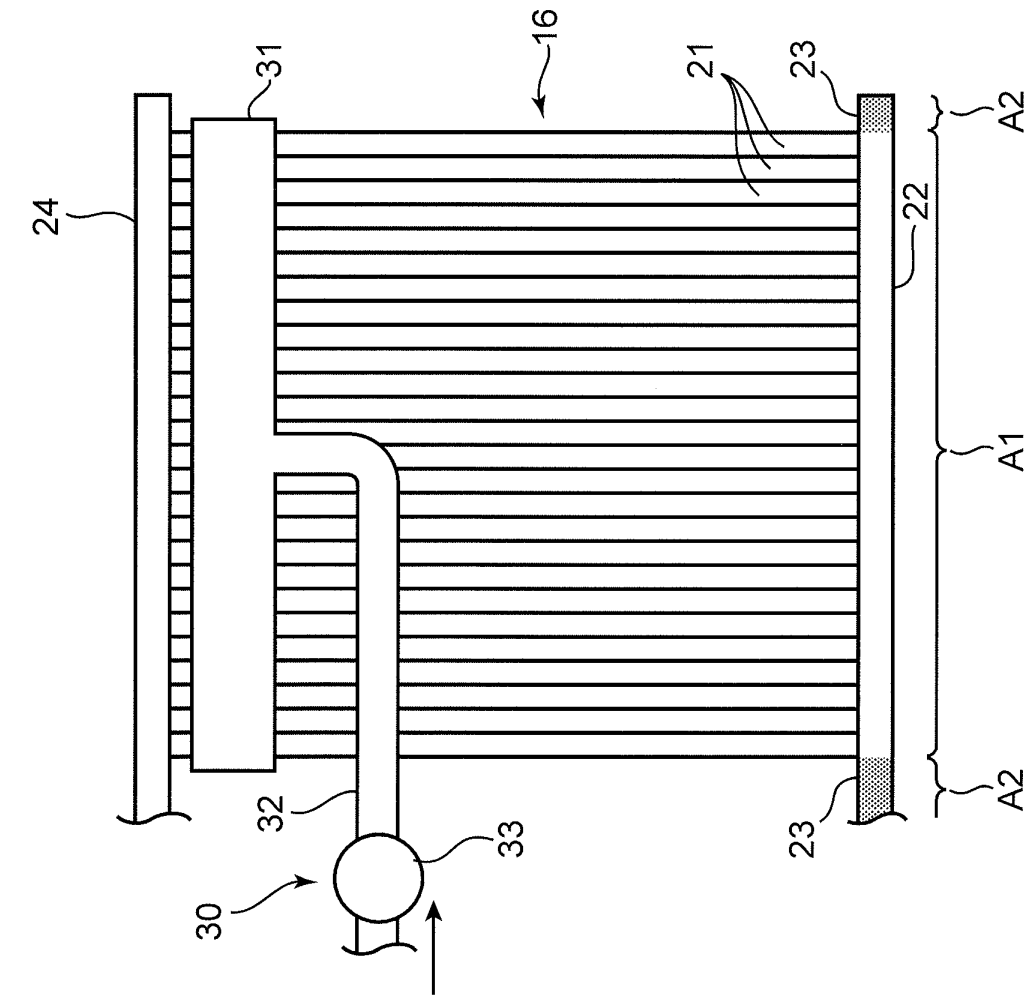


FIG. 5B

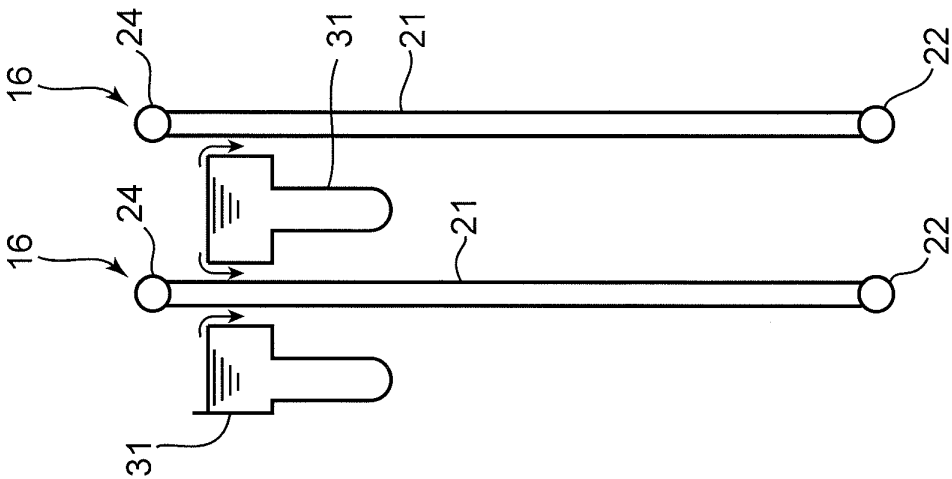


FIG. 6

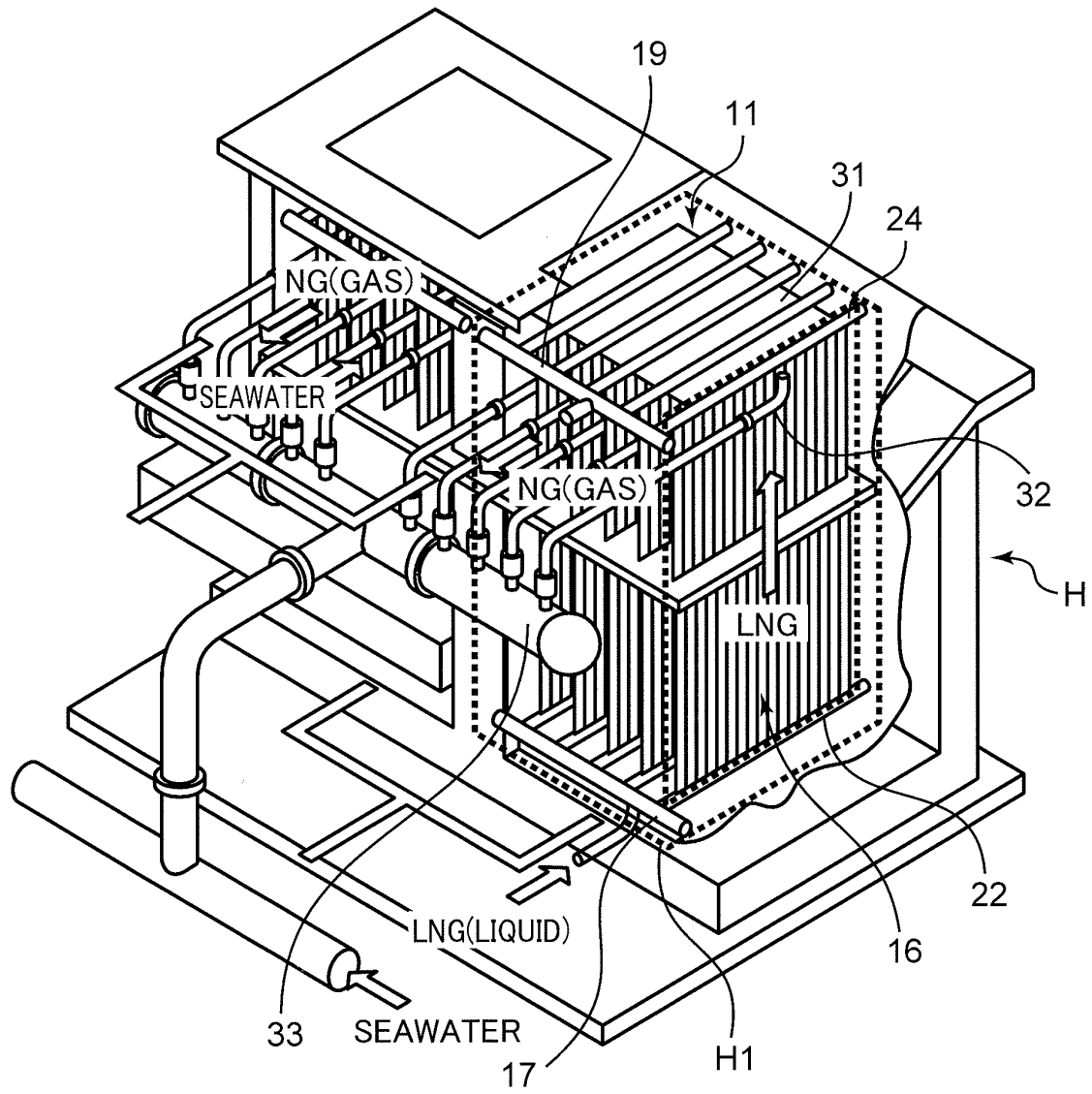


FIG. 7

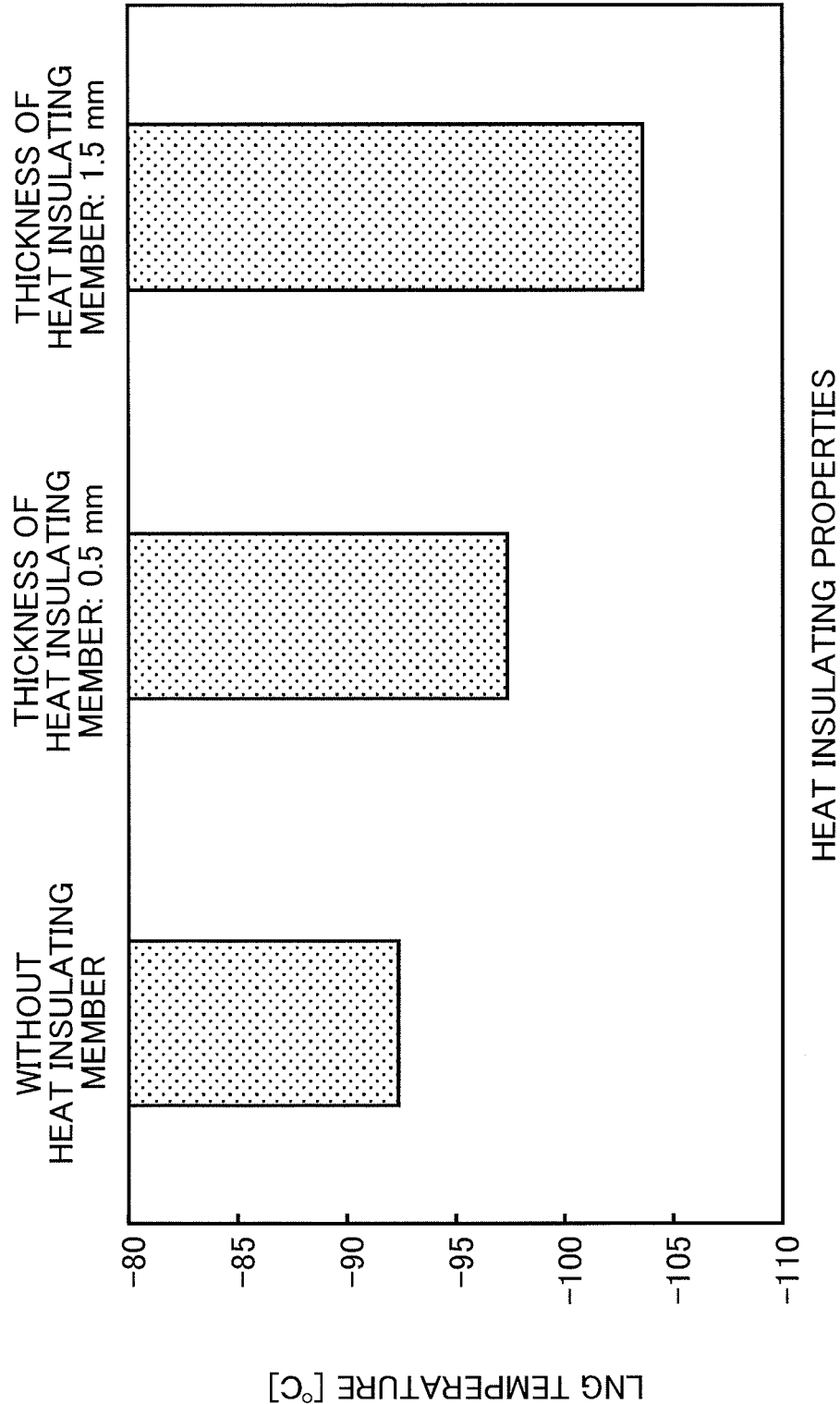


FIG. 8

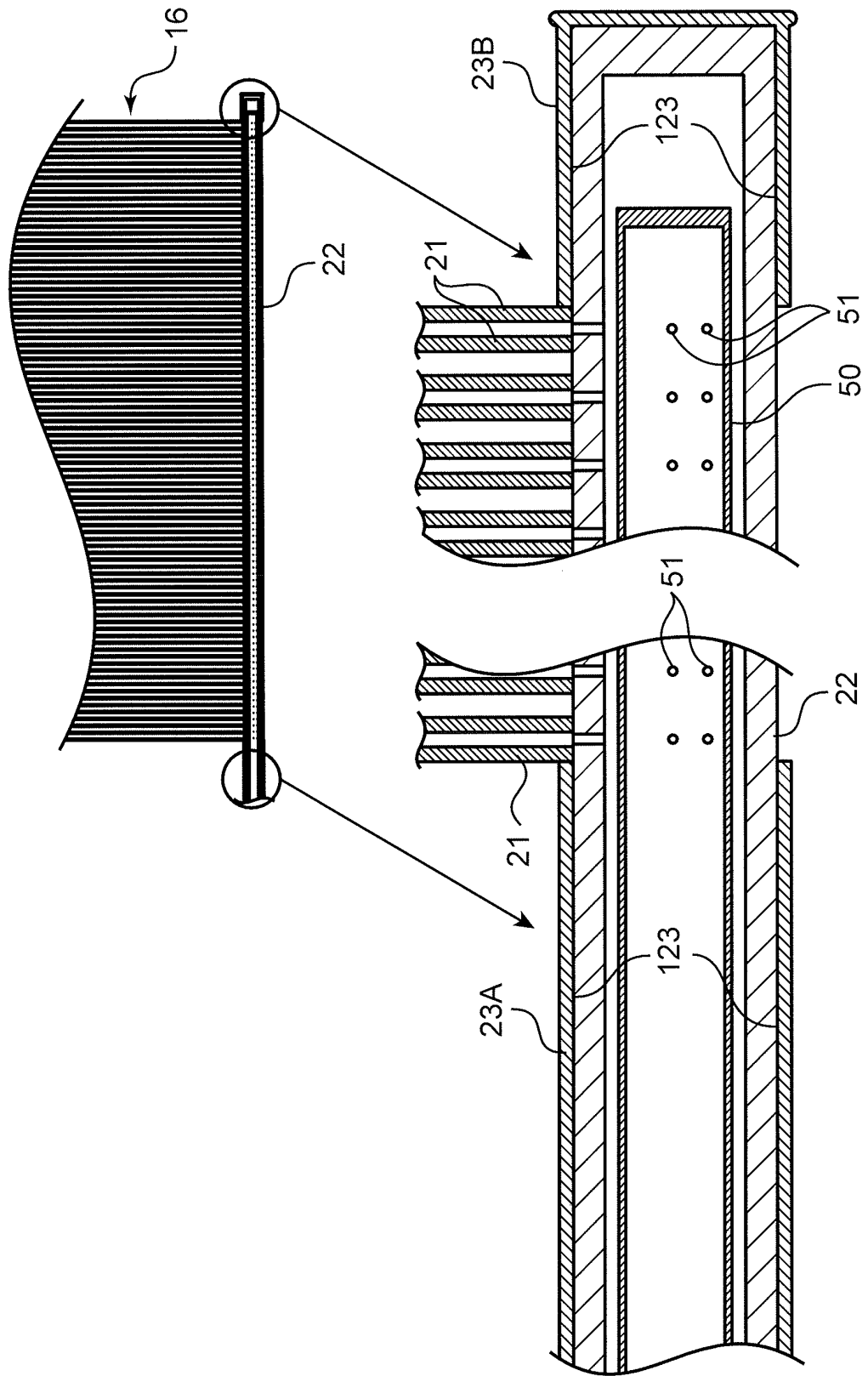


FIG. 9

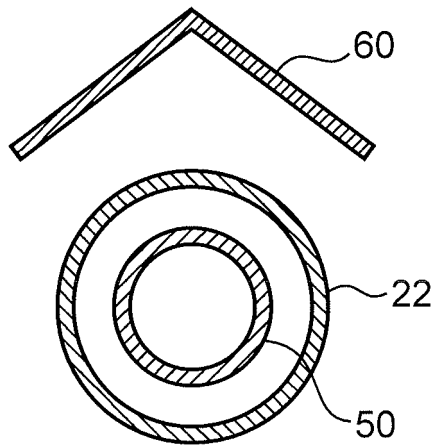


FIG. 10

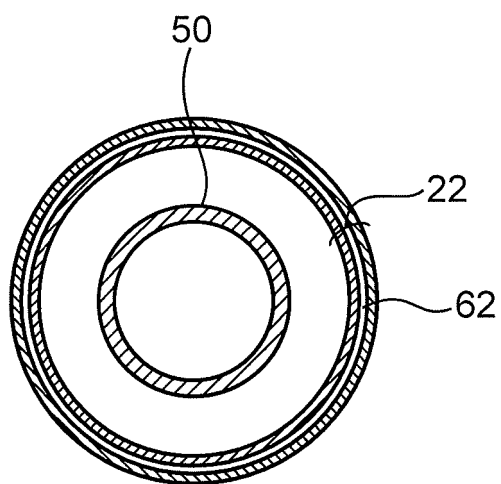
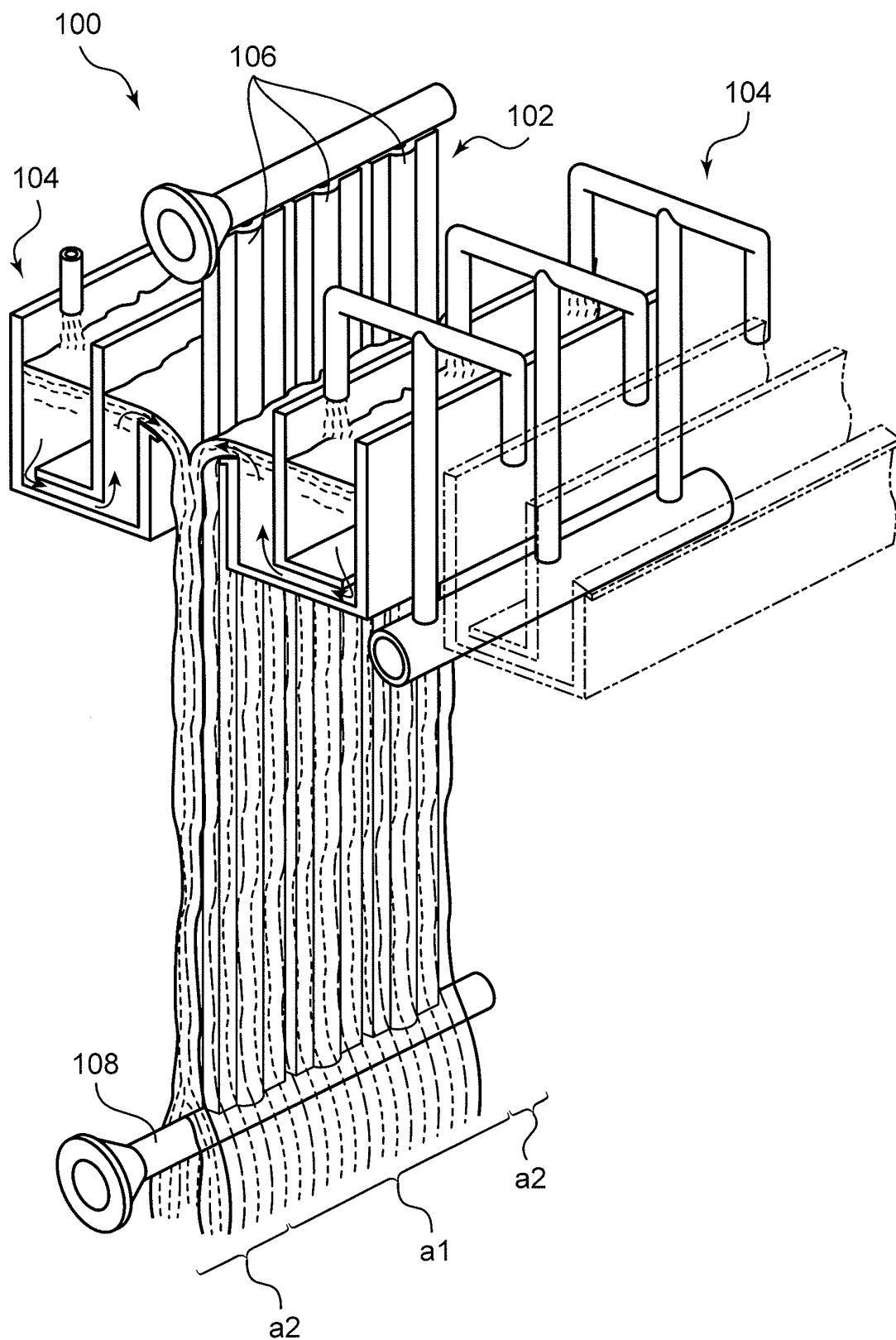


FIG. 11



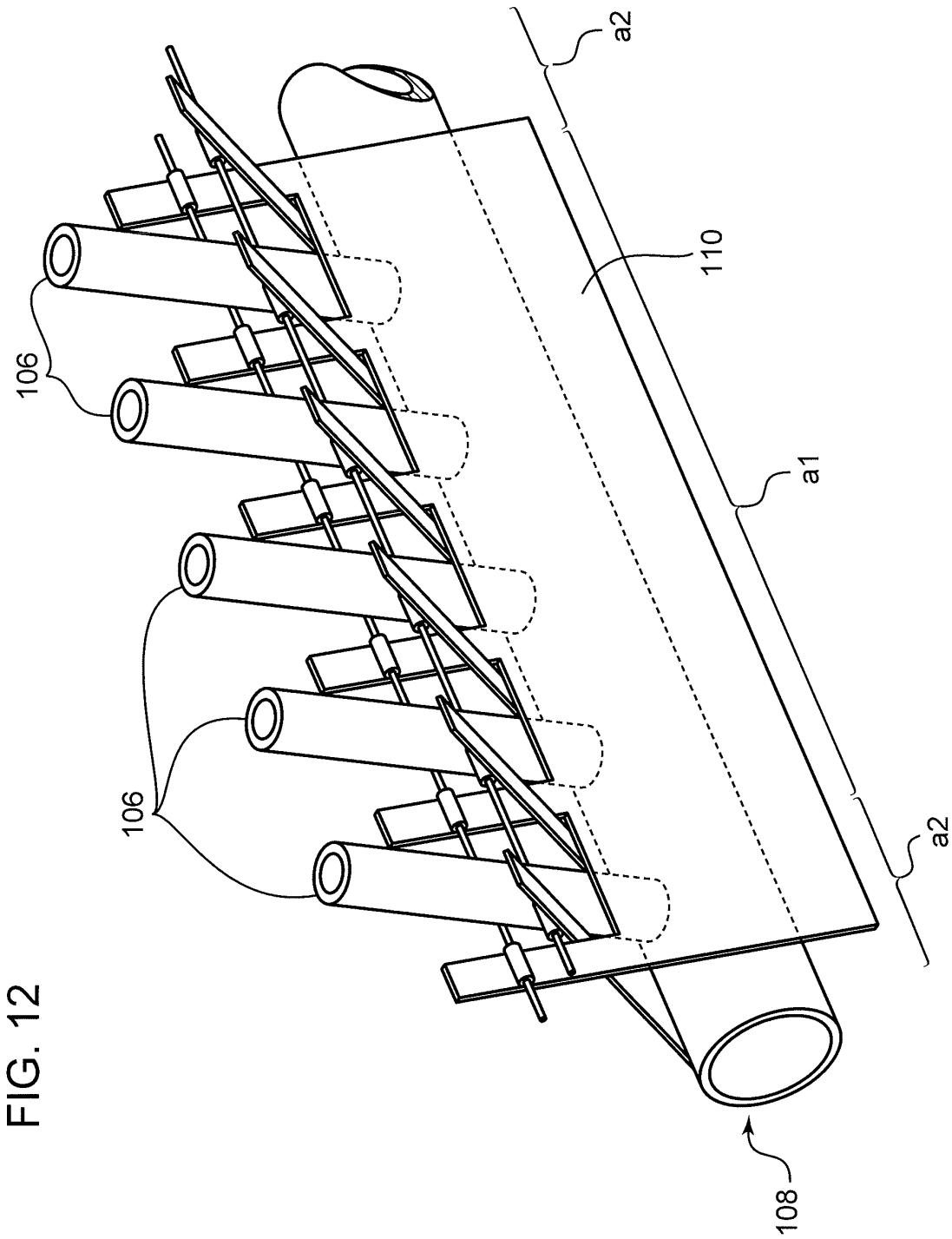


FIG. 12

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/007075

A. CLASSIFICATION OF SUBJECT MATTER

F28D3/02 (2006.01) i, F17C9/02 (2006.01) i

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)

F28D3/02, F17C9/02

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2012
Kokai Jitsuyo Shinan Koho	1971-2012	Toroku Jitsuyo Shinan Koho	1994-2012

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 8-29075 A (Kobe Steel, Ltd.), 02 February 1996 (02.02.1996), entire text; all drawings (particularly, paragraphs [0015], [0016], [0018]; fig. 1 to 3) & US 5806470 A & EP 727632 A1 & WO 1996/002803 A1 & DE 69523283 D & ES 2166827 T	1, 3, 5 2, 4, 6
Y	JP 3-286990 A (Tokyo Gas Co., Ltd.), 17 December 1991 (17.12.1991), entire text; all drawings (particularly, page 4, upper right column, lines 8 to 13; page 5, lower right column, lines 4 to 17; fig. 3) (Family: none)	1, 3, 5

☒ Further documents are listed in the continuation of Box C.☐ See patent family annex.

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"I" 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

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"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
24 January, 2012 (24.01.12)Date of mailing of the international search report
31 January, 2012 (31.01.12)Name and mailing address of the ISA/
Japanese Patent Office

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Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/007075

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 9-317996 A (Sumitomo Precision Products Co., Ltd.), 12 December 1997 (12.12.1997), entire text; all drawings (Family: none)	1, 3, 5
Y	JP 6-26783 A (Kobe Steel, Ltd.), 04 February 1994 (04.02.1994), entire text; all drawings (particularly, paragraphs [0009] to [0016], [0022]; fig. 1 to 3) (Family: none)	1, 3, 5
Y	JP 2007-16968 A (The Kansai Electric Power Co., Inc.), 25 January 2007 (25.01.2007), entire text; all drawings (particularly, paragraphs [0030] to [0032], [0035]; fig. 1, 2, 4) (Family: none)	1, 3, 5
Y	WO 96/02803 A1 (Kobe Steel, Ltd.), 01 February 1996 (01.02.1996), entire text; all drawings (particularly, fig. 19) & JP 8-29075 A & US 5806470 A & EP 727632 A1 & DE 69523283 D & ES 2166827 T	5
A	JP 4-217788 A (Kobe Steel, Ltd.), 07 August 1992 (07.08.1992), entire text; all drawings (particularly, paragraphs [0015] to [0030]; fig. 1, 4, 5) (Family: none)	1, 2, 6
A	JP 56-34758 B2 (Osaka Gas Co., Ltd.), 12 August 1981 (12.08.1981), entire text; all drawings (Family: none)	4
A	JP 8-183970 A (Tokyo Gas Co., Ltd.), 16 July 1996 (16.07.1996), entire text; all drawings (Family: none)	4

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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- JP 8183970 A [0013]