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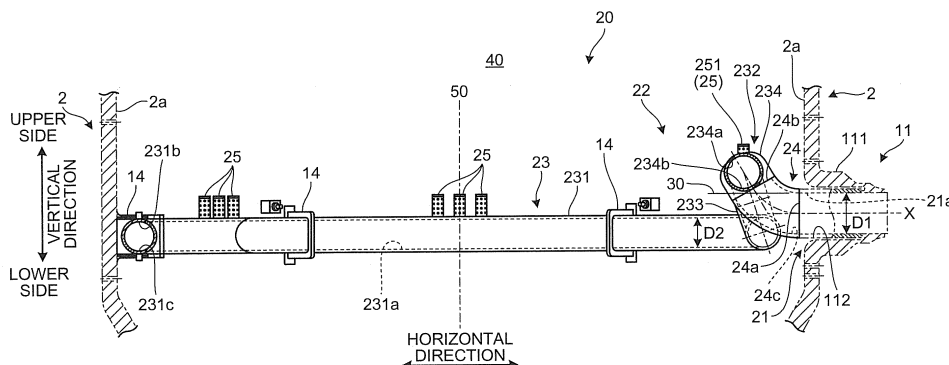
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(54) **WATER SUPPLY PIPE FOR STEAM GENERATOR**

(57) The water supply tube for steam generator includes an insert tube portion (21) inserted in a penetration hole (112) of a shell member and a generator internal tube portion (22) connected to the insert tube portion. The generator internal tube portion includes a tubular passage and an effluence tube (25) allowing effluence of cooling water in the tubular passage to a space (40) in a steam generator. The tubular passage includes a first tilted portion (24c) in which a side having a greater distance from the insert tube portion along a flow direction is located vertically higher than a side having a smaller distance from the insert tube portion and a second tilted portion which is located with a greater distance from the

insert tube portion than the first tilted portion. In the second tilted portion, a side having a greater distance from the insert tube portion along the flow direction is located vertically lower than a side having a smaller distance from the insert tube portion. In at least a portion of a section, along the flow direction, of the tubular passage (234a) between the first tilted portion and the second tilted portion, a bottom end (234b) of a cross section of the tubular passage is arranged vertically higher than a horizontal plane (30) including a top end (21a) of an inner wall surface of the insert tube portion at a connection between the insert tube portion and the generator internal tube portion.

FIG.2



Description

Field

[0001] The present invention relates to a water supply tube for a steam generator.

Background

[0002] Conventionally, a water supply tube for supplying cooling water into a steam generator of a pressurized water reactor or the like is known. When steam or high-temperature water in a generator flows into a water supply tube or such similar state happens, thermal stratification may occur in the water supply tube. Thermal stratification might generate stress causing fatigue and therefore is not preferable.

[0003] In Patent Literature 1, a technique applied to a water supply tube for a steam generator is disclosed, in which a dam is attached to an inner upper wall of the water supply tube bent to raise a water supply ring.

Citation List

Patent Literature

[0004] Patent Literature 1: Japanese Utility Model Laid-open No. 61-121304

Summary

Technical Problem

[0005] Further consideration can be made to prevent thermal stratification in a water supply tube. The object of the present invention is to provide a water supply tube for a steam generator capable of suppressing thermal stratification in the tube.

Solution to Problem

[0006] According to an aspect of the present invention, a water supply tube for a steam generator includes: an insert tube portion horizontally extending and configured to be inserted in a penetration hole penetrating a shell member of the steam generator; and a generator internal tube portion connected to the insert tube portion and arranged inside the steam generator. The generator internal tube portion includes a tubular passage formed in an axial direction of the generator internal tube portion and an effluence unit allowing effluence of cooling water in the tubular passage from the tubular passage to a space in the steam generator, the tubular passage allowing cooling water supplied from outside the steam generator via the insert tube portion to flow in the tubular passage. The tubular passage includes a first tilted portion which is tilted so that a side having a greater distance from the insert tube portion along a flow direction of cooling water

is located vertically higher than a side having a smaller distance from the insert tube portion and a second tilted portion which is located with a greater distance from the insert tube portion along the flow direction than the first tilted portion and is tilted so that a side having a greater distance from the insert tube portion along the flow direction is located vertically lower than a side having a smaller distance from the insert tube portion. In at least a portion of a section, along the flow direction, of the tubular passage between the first tilted portion and the second tilted portion, a bottom end of a cross section, perpendicular to the flow direction, of the tubular passage is arranged vertically higher than a horizontal plane including a top end of an inner wall surface of the insert tube portion at a connection between the insert tube portion and the generator internal tube portion.

[0007] According to the water supply tube for a steam generator, thermal stratification caused by a steam-pocket generated in an insert tube portion can be suppressed by suppressing the decrease in water level in the insert tube portion. Further, in a case when the cooling water having different temperature from the cooling water in the insert tube portion flows in, the effluence of the cooling water having high temperature to the generator internal tube portion is generated to suppress the thermal stratification.

[0008] Advantageously, in the water supply tube for a steam generator, the effluence unit is not included in a section, of the generator internal tube portion, in which the first tilted portion is formed.

[0009] According to the water supply tube for a steam generator, the decrease in water level in the insert tube portion can be suppressed even when the cooling water level in the steam generator decreases.

[0010] Advantageously, in the water supply tube for a steam generator, the generator internal tube portion includes a ring tube portion extending in a ring shape along an inner circumferential surface of the shell member and a connection tube portion branching off from the ring tube portion to connect the ring tube portion and the insert tube portion. The first tilted portion is provided as the tubular passage formed in the connection tube portion, and the second tilted portion is provided as the tubular passage formed in the ring tube portion, the second tilted portion being formed on each of both ends, in an axial direction, of the ring tube portion with the connection tube portion in between.

[0011] According to the water supply tube for a steam generator, a first tilted portion and a second tilted portion can be formed by suppressing interference against other structures in the steam generator.

[0012] Advantageously, in the water supply tube for a steam generator, a horizontal ring tubular passage which is the tubular passage extending in a horizontal direction is formed in a portion, arranged farther than the second tilted portion from the insert tube portion along the flow direction, of the ring tube portion, and a top end of a cross section, perpendicular to the flow direction, of the hori-

zontal ring tubular passage is provided vertically lower than the horizontal plane including the top end of the inner wall surface of the insert tube portion at the connection between the insert tube portion and the generator internal tube portion.

[0013] According to the water supply tube for a steam generator, when the cooling water level in the steam generator decreases, generation of a steam-pocket in a horizontal ring tubular passage is suppressed since exposure of a ring tube portion is suppressed.

[0014] Advantageously, in the water supply tube for a steam generator, a horizontal ring tubular passage which is the tubular passage extending in a horizontal direction is formed in a portion, arranged farther than the second tilted portion from the insert tube portion along the flow direction, of the ring tube portion, and a top end of a cross section, perpendicular to the flow direction, of the horizontal ring tubular passage is arranged vertically lower than a lower limit of a target for controlling a water level of cooling water in the space in the steam generator.

[0015] According to the water supply tube for a steam generator, even when the cooling water level in the steam generator decreases to a lower limit of the target for controlling the water level, generation of a steam-pocket in the horizontal ring tubular passage is suppressed. Advantageous Effects of Invention

[0016] According to the present invention, the thermal stratification in a water supply tube for a steam generator can be suppressed.

Brief Description of Drawings

[0017]

FIG. 1 is a schematic view of a steam generator according to an embodiment.

FIG. 2 is a cross sectional view of the water supply tube for a steam generator according to the embodiment.

FIG. 3 is a perspective view illustrating the water supply tube for a steam generator according to the embodiment.

FIG. 4 is a perspective view illustrating an essential portion of the water supply tube for a steam generator according to the embodiment.

FIG. 5 is a cross sectional view illustrating an example of the water supply tube capable of suppressing thermal stratification in an insert tube portion.

FIG. 6 is a perspective view illustrating an example of the water supply tube capable of suppressing thermal stratification in the insert tube portion.

Description of Embodiments

[0018] A water supply tube for a steam generator according to an embodiment of the present invention will be described below in detail referring to the drawings. The present invention is not limited to the embodiment.

The component of the embodiment described below includes such component which can easily be conceived by those skilled in the art, or components substantially the same.

Embodiment

[0019] The embodiment will be described referring to FIG. 1 to FIG. 6. The embodiment relates to a water supply tube for a steam generator. FIG. 1 is a schematic view of a steam generator according to the embodiment. FIG. 2 is a cross sectional view of a water supply tube for a steam generator according to the embodiment. FIG. 3 is a perspective view illustrating the water supply tube for a steam generator according to the embodiment. FIG. 4 is a perspective view illustrating an essential portion of the water supply tube for a steam generator according to the embodiment. Note that, FIG. 2 illustrates a cross section of the water supply tube for a steam generator viewed along the horizontal direction as shown in the arrow I in FIG. 3.

[0020] The steam generator 1 is used for, for example, the PWR (Pressurized Water Reactor). Light water is used as a nuclear reactor coolant and a neutron moderator in the pressurized water reactor. In the pressurized water reactor, light water with high temperature and high pressure, which does not boil throughout the reactor internal, is supplied to the steam generator 1 as primary cooling water. The steam generator 1 transfers the heat of the high-temperature and high-pressure primary cooling water to secondary cooling water to generate steam in the secondary cooling water. With this steam, a turbine generator is rotated to produce power.

[0021] The steam generator 1 extends in the up-and-down direction to form a sealed hollow cylindrical shape. The steam generator 1 includes a body portion 2 having an upper half portion and a lower half portion of which diameter is slightly smaller than that of the upper half portion. The body portion 2 is a shell member of the steam generator 1. In the lower half portion of the body portion 2, a tube bundle shroud 3 formed in a cylindrical shape is provided so as to be arranged with a predetermined gap against the inner wall surface of the body portion 2. The tube bundle shroud 3 extends downward so that the bottom end portion of the tube bundle shroud 3 is located just above the tube plate 4 arranged in the lower part of the lower half portion of the body portion 2. A heat exchange tube bundle 51 composed of a plurality of heat exchange tubes 5 each formed in an inverted U-shape is provided in the tube bundle shroud 3. Each heat exchanger tube 5 is arranged so as the U-shaped arc portion to be in the upper side. The end portion in the bottom side of each heat exchanger tube 5 is supported by the tube plate 4 and the middle portion of each heat exchanger tube 5 is supported by a plurality of tube supporting plates 6. In the tube supporting plate 6, a large number of penetration holes (not shown in the drawing), in each of which the heat exchanger tube 5 is inserted to be sup-

ported, are formed.

[0022] In the bottom end portion of the body portion 2, a channel head 7 is provided. A partition wall 8 divides the inside of the channel head 7 into an inlet chamber 71 and an outlet chamber 72. One of ends of each heat exchanger tube 5 is connected to the inlet chamber 71 and the other end of each heat exchanger tube 5 is connected to the outlet chamber 72. The inlet chamber 71 has an inlet nozzle 711 communicating with the outside of the body portion 2. The outlet chamber 72 has an outlet nozzle 721 communicating with the outside of the body portion 2. A cooling water pipe (not shown in the drawing) through which the primary cooling water is supplied from the pressurized water reactor is connected to the inlet nozzle 711. A cooling water pipe (not shown in the drawing) through which the primary cooling water, after exchanging heat, is supplied to the pressurized water reactor is connected to the outlet nozzle 721.

[0023] Provided in the upper half portion of the body portion 2 are a steam-water separator 9 which separates the steam flow into steam and hot water and a moisture separator 10 which removes moisture from the separated steam to provide a steam condition close to the dry steam. Between the steam-water separator 9 and the heat exchange tube bundle 51, a water supply tube for a steam generator for supplying a secondary cooling water into the body portion 2 from outside (hereinafter simply referred to as a "water supply tube") 20 is inserted. A steam discharge port 12 is formed on the top end portion of the body portion 2. Provided in the lower half portion of the body portion 2 is a water supply passage 13 which allows the secondary cooling water supplied from the water supply tube 20 into the body portion 2 to fall through the gap between the body portion 2 and the tube bundle shroud 3, make turn at the tube plate 4, and ascend along the heat exchange tube bundle 51. Note that, a steam supply passage (not shown in the drawing) for supplying steam to the turbine is connected to the steam discharge port 12. A cooling water pipe (not shown in the drawing) for supplying the secondary cooling water recovered in a steam condenser (not shown in the drawing), by cooling the steam used in the turbine, is connected to the water supply tube 20.

[0024] In the steam generator 1 as described above, the primary cooling water heated in the pressurized water reactor is transferred to the inlet chamber 71 and finally to the outlet chamber 72 by passing through a large number of heat exchange tubes 5. Further, the secondary cooling water cooled by the steam condenser is transferred to the water supply tube 20, and then supplied into the body portion 2 via the water supply tube 20. In the embodiment, the secondary cooling water may be simply referred to as "cooling water." The cooling water supplied to the body portion 2 ascends along the heat exchange tube bundle 51, passing through the water supply passage 13. In this step, heat is exchanged between the high-pressure and high-temperature primary cooling water and the secondary cooling water. Then, the cooled

primary cooling water returns to the pressurized water reactor through the outlet chamber 72. Further, the secondary cooling water which exchanged heat with the high-pressure and high-temperature primary cooling water ascends in the body portion 2 and is separated into steam and hot water in the steam-water separator 9. Then, the moisture is removed in the moisture separator 10 and the separated steam is transferred to the turbine.

[0025] The water supply tube 20 includes a tubular passage in which the cooling water supplied from outside the steam generator 1 flows and an effluence tube 25 which allows effluence of the cooling water in the tubular passage to a space 40 in the steam generator 1 (see FIG. 2 to FIG. 4). The water supply tube 20 is arranged so as to allow effluence of the cooling water below the water level of the cooling water in the space 40 during the operation of the steam generator 1. When supplying of the cooling water from outside the steam generator 1 stops or starts, such as in a shutdown and a startup of a nuclear reactor plant, thermal stratification may occur in the water supply tube 20. For example, when a cooling water with low temperature is supplied, with a small flow rate, to the water supply tube 20 containing high-temperature cooling water or steam, thermal stratification between the cooling water with low temperature and the cooling water with high temperature may occur inside the tube, or thermal stratification between steam and cooling water may occur. When thermal stratification is generated in the tube, stress causing fatigue is generated, which is not preferable. It is preferable if thermal stratification in the water supply tube 20 can be suppressed. Particularly, it is preferable if thermal stratification can be suppressed in the portion of the water supply tube 20 which is inserted in a penetration hole penetrating the body portion 2.

[0026] In the steam generator 1, as will be described referring to FIG. 2 to FIG. 4, a generator internal tube portion 22 of the water supply tube 20 of the embodiment is arranged inside the steam generator 1 and includes a connection tube portion 24 (e.g., see FIG. 2) bent to raise the downstream side from the insert tube portion 21 inserted in the penetration hole 112 penetrating the body portion 2 and a tilted tube portion 233 (e.g., see FIG. 2) bent to lower the further downstream side. Since the bent portion is provided to raise the downstream side, along the flow direction of the cooling water supplied from outside, from the insert tube portion 21, the cooling water passes through the insert tube portion 21 within a short period of time before developing thermal stratification so that generation of thermal stress in the body portion 2 is suppressed. Further, since the water supply tube 20 which is first bent to raise the downstream side is then bent to lower the further downstream side, the degree of freedom of water supply tube 20 in designing arrangement regarding other structures in the steam generator 1 and the degree of freedom in designing elevation of the water level in the generator are provided.

[0027] As illustrated in FIG. 2, the water supply tube

20 includes the insert tube portion 21 and the generator internal tube portion 22. Both the insert tube portion 21 and the generator internal tube portion 22 are tubular members having a circular cross section. A tubular passage is formed along each axial direction of the insert tube portion 21 and the generator internal tube portion 22. The cooling water supplied from outside the steam generator 1 flows through the tubular passage of the generator internal tube portion 22 via the insert tube portion 21. The effluence of the cooling water flowing through the tubular passage of the generator internal tube portion 22 from the tubular passage of the generator internal tube portion 22 to the space 40 in the steam generator 1 via an effluence tube 25, which will be described below, is generated.

[0028] The body portion 2 includes a nozzle 11. The nozzle 11 includes a protrusion 111 protruding toward the radially outward direction of the body portion 2. In the nozzle 11, a penetration hole 112 penetrating the nozzle 11 along the axial direction of the protrusion 111 is formed. The insert tube portion 21 engages with the penetration hole 112 from the radially inner side of the body portion 2. The insert tube portion 21 is secured to the nozzle 11 by welding or the like so that the outer circumferential surface of the insert tube portion 21 and the inner circumferential surface of the protrusion 111 face each other. That is, the insert tube portion 21 is inserted in the penetration hole 112 penetrating the body portion 2 of the steam generator 1. The central axis of the nozzle 11, that is, the central axis of the penetration hole 112 is horizontally provided and correspondingly, the insert tube portion 21 extends in the horizontal direction. Further, the insert tube portion 21 linearly extends along the radial direction of the body portion 2.

[0029] The generator internal tube portion 22 is arranged inside the body portion 2, that is, inside the steam generator 1. As illustrated in FIG. 2 and FIG. 3, the generator internal tube portion 22 includes a ring tube portion 23 extending in a ring shape and a connection tube portion 24 branching off from the ring tube portion 23 to connect the ring tube portion 23 and the insert tube portion 21. The ring tube portion 23 extends along the circumferential direction of the body portion 2, routing along the inner wall surface 2a of the body portion 2 illustrated in FIG. 2. For example, the ring tube portion 23 is arranged on the same axis as the central axis 50 of the body portion 2. As illustrated in FIG. 2, the ring tube portion 23 is supported on the inner wall surface 2a of the body portion 2 via a stay 14. The ring tube portion 23 includes a horizontal ring tube portion 231 and an upper ring tube portion 232 raised vertically higher than the horizontal ring tube portion 231.

[0030] The horizontal ring tube portion 231 extends in the horizontal direction. As illustrated in FIG. 2, the tubular passage formed in the horizontal ring tube portion 231 along the axial direction, that is, a horizontal ring tubular passage 231a also extends in the horizontal direction. That is, the top end 231b in any of cross sections, per-

pendicular to the flow direction of the cooling water, of the horizontal ring tubular passage 231a has the same vertical location. Further, the bottom end 231c in any of cross sections, perpendicular to the flow direction of the cooling water, of the horizontal ring tubular passage 231a has the same vertical location. In other words, the central axis of the horizontal ring tubular passage 231a extends on the same horizontal plane and the horizontal ring tubular passage 231a has a constant diameter. In the ring tube portion 23, the horizontal ring tube portion 231 in which the horizontal ring tubular passage 231a is formed is arranged farther than the tilted tube portion 233, along the flow direction of the cooling water, from the insert tube portion 21. That is, the horizontal ring tubular passage 231a is arranged in the downstream side, in the flow direction of the cooling water supplied from outside the steam generator 1, than the tubular passage 233e of the tilted tube portion 233.

[0031] As illustrated in FIG. 3, the upper ring tube portion 232 includes two tilted tube portions 233 and an upper horizontal tube portion 234. The tilted tube portion 233 is connected to the insert tube portion 21 via the upper horizontal tube portion 234 and the connection tube portion 24. That is, the tilted tube portion 233 is located with the longer distance, along the flow direction of the cooling water in the generator internal tube portion 22, from the insert tube portion 21 than the connection tube portion 24. In other words, the distance of the flow passage from the insert tube portion 21 to the tilted tube portion 233 is longer than the distance of the flow passage from the insert tube portion 21 to the connection tube portion 24.

[0032] The upper horizontal tube portion 234 is a linear tube portion extending in the horizontal direction. The connection tube portion 24 branches off from the upper horizontal tube portion 234. The connection tube portion 24 branches off from the bottom portion of the upper horizontal tube portion 234 toward the outer side along the radial direction of the body portion 2. The end portion, in the side opposite to the side connected to the upper horizontal tube portion 234, of the connection tube portion 24 is connected to the insert tube portion 21. That is, the connection tube portion 24 branches off from the ring tube portion 23 to connect the ring tube portion 23 and the insert tube portion 21. The connection tube portion 24 is tilted so that the side having the greater distance from the insert tube portion 21 along the flow direction of the cooling water is located vertically higher than the side having the smaller distance from the insert tube portion 21. That is, the connection tube portion 24 is tilted so that the end portion 24b side connected to the upper horizontal tube portion 234 is located vertically higher than the end portion 24a side connected to the insert tube portion 21. Accordingly, the tubular passage 24c formed in the connection tube portion 24 is tilted so that the side having the greater distance from the insert tube portion 21 along the flow direction of the cooling water is located vertically higher than the side having the smaller distance from the

insert tube portion 21. The tubular passage 24c formed in the connection tube portion 24 corresponds to a first tilted portion. As for the tubular passage 24c, the gradient of the flow passage is greater at a location with a greater distance from the insert tube portion 21 than a location with a smaller distance from the insert tube portion 21.

[0033] The tilted tube portions 233 are formed on respective both sides, in the axial direction, of the ring tube portion 23 with the connection tube portion 24 in between. One of tilted tube portions 233 connects one of ends of the upper horizontal tube portion 234 and one of ends of the horizontal ring tube portion 231. The other of tilted tube portions 233 connects the other end of the upper horizontal tube portion 234 and the other end of the horizontal ring tube portion 231. The tilted tube portion 233 is tilted so that the side having the greater distance from the insert tube portion 21 along the flow direction of the cooling water is located vertically lower than the side having the smaller distance from the insert tube portion 21. That is, as illustrated in FIG. 4, the tilted tube portion 233 is tilted so that the side with the end portion 233b connected to the horizontal ring tube portion 231 is located vertically lower than the side with the end portion 233a connected to the upper horizontal tube portion 234. Accordingly, the tubular passage 233e formed in the tilted tube portion 233 is tilted so that the side having the greater distance from the insert tube portion 21 along the flow direction of the cooling water is located vertically lower than the side having the smaller distance from the insert tube portion 21. The tubular passage 233e corresponds to a second tilted portion.

[0034] The tilted tube portion 233 of the embodiment includes two elbow parts 233c and 233d which are connected in serial. One of the elbow parts, that is, 233c extends toward the vertically higher side from a connection 233g between two elbows and is bent toward one of the sides along the circumferential direction. The other elbow part, that is, 233d extends toward the vertically lower side from the connection 233g and is bent toward the other side along the circumferential direction. In this manner, the tilted tube portion 233 is bent downward from the upper horizontal tube portion 234 to be connected to the horizontal ring tube portion 231. Further, as illustrated in FIG. 2, the tilted tube portion 233 is tilted so that the vertically lower side of the tilted tube portion 233 is located in radially outer side of the body portion 2 than the vertically higher side of the tilted tube portion 233. That is, the vertically lower side of the tilted tube portion 233 is closer to the inner wall surface 2a of the body portion 2 than the vertically higher side of the tilted tube portion 233. Arranged in this manner, even when any other structure is arranged in the radially inner region of the body portion 2, the ring tube portion 23 can be arranged without interfering with the other structure. Note that, the tilt in the radial direction of the tilted tube portion 233 is not limited to the configuration described above. The tilt of the tilted tube portion 233 may suitably be determined in any direction as long as the interference between other

structures and the ring tube portion 23 can be avoided.

[0035] Further, since the first tilted portion, which is an upward-bent portion of the tubular passage, is formed in the connection tube portion 24 as the tubular passage 24c and the second tilted portion, which is a downward-bent portion of the tubular passage, is formed in the ring tube portion 23 as the tubular passage 233e, a large degree of freedom is provided to the arrangement of the upward-bent portion and the downward-bent portion of the tubular passage. In the generator internal tube portion 22 of the embodiment, the ring tube portion 23 is formed in the circumferential direction, branching from both sides of the connection tube portion 24. If both the first tilted portion, which is the upward-bent portion, and the second tilted portion, which is the downward-bent portion, are to be formed in the connection tube portion 24, that is, at a location upstream of the location from which the ring tube portion 23 branches, a large space is necessary. If both the first tilted portion and the second tilted portion are to be formed in the connection tube portion 24, the connection tube portion 24 needs to be bent in a U-shape or a V-shape, resulting in the connection tube portion 24 greatly protruding along the radial direction toward the center of the body portion 2. As a result, the connection tube portion 24 is likely to interfere with other structures.

[0036] Contrarily, by forming the tubular passage 233e as the second tilted portion in the ring tube portion 23 branching from the connection tube portion 24, the space for forming the second tilted portion is easily provided. According to the technique of forming the second tilted portion (tubular passage 233e) by tilting the portion of the ring tube portion 23 as in the embodiment, the second tilted portion can extend along the circumferential direction. That is, the second tilted portion can be formed avoiding interference with the structure arranged in the central side along the radial direction of the body portion 2. Therefore, the degree of freedom of arranging the second tilted portion is large. For example, as described above, the interference with other structures can be avoided by providing a tilt to the tilted tube portion 233 so that the vertically lower side of the tilted tube portion 233 is arranged in the radially outer side of the body portion 2 than the vertically higher side of the tilted tube portion 233.

[0037] A constant tube diameter (inner diameter) can be provided for each of the insert tube portion 21, the connection tube portion 24, and the ring tube portion 23. In the embodiment, tube diameters of the insert tube portion 21 and the connection tube portion 24 are the same, and the tube diameter of the ring tube portion 23 is smaller than the tube diameter of the connection tube portion 24.

[0038] The ring tube portion 23 includes an effluence tube 25. The effluence tube 25 functions as an effluence unit to allow effluence of cooling water, in the tubular passage formed in the ring tube portion 23, from the tubular passage to the space 40 in the steam generator 1. The effluence tube 25 is a hollow cylindrical member. A plurality of effluence tubes 25 is arranged on the ring tube

portion 23 along the extending direction of the ring tube portion 23. As illustrated in FIG. 4, a plurality of penetration holes 25a, penetrating the cylindrical portion of the effluence tube 25 in the radial direction, is provided in the cylindrical portion of the effluence tube 25. Further, one of ends of the effluence tube 25 in the axial direction is connected to the tubular passage of the ring tube portion 23 via a flow hole, which is not illustrated in the drawing, formed in the ring tube portion 23. The flow hole is formed in the top portion of the ring tube portion 23. That is, the effluence tube 25 is connected to the upper end of the tubular passage, when viewed from the axial direction of the tubular passage, formed in the ring tube portion 23. The end portion in the vertically higher side of the effluence tube 25, that is, the end portion in the opposite side to the end portion connected to the ring tube portion 23 is closed.

[0039] When the cooling water is supplied to the ring tube portion 23 via the insert tube portion 21 from outside the steam generator 1, the cooling water flows into the effluence tube 25 from the tubular passage of the ring tube portion 23, and then effluence of the cooling water into the space 40 in the steam generator 1 is generated via the penetration hole 25a. A large number of penetration holes 25a are uniformly arranged in the circumferential direction and the axial direction in the effluence tube 25. Therefore, uniform effluence of the cooling water is generated around the effluence tube 25. Note that, the effluence tube 25 is not provided on the connection tube portion 24, that is, the section, in which the first tilted portion is formed, in the generator internal tube portion 22.

[0040] Since the flow hole communicating between the tubular passage of the ring tube portion 23 and the effluence tube 25 are formed on the ridge of the ring tube portion 23, the decrease in the water level of the cooling water in the tubular passage of the ring tube portion 23 is suppressed, even when the water level of the cooling water in the steam generator 1 is low enough to expose the ring tube portion 23 above the water level. In this manner, the generation of a steam-pocket in the tubular passage of the ring tube portion 23 is suppressed.

[0041] Further, in the water supply tube 20 of the embodiment, the bottom end 234b of the cross section of the tubular passage 234a formed in the upper horizontal tube portion 234 is located vertically higher than the top end 21a of the inner wall surface of the insert tube portion 21. In this manner, the generation of thermal stratification in the insert tube portion 21 is suppressed as will be described below.

[0042] As illustrated in FIG. 2, the bottom end 234b of the cross section, perpendicular to the flow direction of the cooling water, of the tubular passage 234a formed in the upper horizontal tube portion 234 is located vertically higher than the top end 21a of the inner wall surface of the insert tube portion 21 at the connection between the insert tube portion 21 and the connection tube portion 24. In other words, the cross section, perpendicular to

the flow direction of the cooling water, of the tubular passage 234a does not intersect with a horizontal plane 30 including the top end 21a of the inner wall surface of the insert tube portion 21 at the connection between the insert tube portion 21 and the connection tube portion 24. At the same time, the bottom end 234b of the cross section is located vertically higher than the horizontal plane 30. In this manner, even when the water level of the cooling water in the steam generator 1 decreases, the decrease in the water level in the tube, which is in the insert tube portion 21 side from the upper horizontal tube portion 234, of the water supply tube 20 can be suppressed. Specifically, the decrease in the water level of the cooling water is suppressed so that the water level will not to be lower than the bottom end 234b of the tubular passage 234a, thereby keeping the insert tube portion 21 filled with the cooling water. As a result, in the insert tube portion 21, the generation of the steam-pocket in the tube is suppressed, thereby suppressing generation of thermal stratification in the insert tube portion 21. Particularly, the connection tube portion 24 of the embodiment does not include the effluence tube 25. Therefore, the decrease in the water level of the cooling water is surely suppressed so that the water level will not be lower than the bottom end 234b of the tubular passage 234a.

[0043] Different from the water supply tube 20 of the embodiment, a certain period of time is necessary for the whole water supply tube to be filled with the cooling water after start supplying cooling water to the water supply tube containing a low level of water as in the start of the operation of steam generator 1. Such is the case for a water supply tube which includes the insert tube portion 21 and the ring tube portion 23 horizontally extending in the same height and does not have an upward-bent portion like the connection tube portion 24 or a downward-bent portion like the tilted tube portion 233. Until the water level in the water supply tube rises to the enough level, layers of steam and cooling water separately exist in the insert tube portion 21, with the generated stress remaining in the insert tube portion 21 causing fatigue. Further, a water hammer may occur by the steam making contact with the cooling water. It is desirable to suppress these thermal stress and water hammer in the vicinity of the nozzle 11 provided as a boundary.

[0044] According to the water supply tube 20 of the embodiment, when supplying of the cooling water to the water supply tube 20 containing a low level of water starts, first, the insert tube portion 21 is filled with the cooling water, and then after the rise in the water level, the cooling water is supplied from the connection tube portion 24 to the horizontal ring tube portion 231 via the upper ring tube portion 232. In this manner, the period of time in which the steam layer and the cooling water layer are generated in the insert tube portion 21 can be shortened, thereby suppressing generation of stress causing fatigue in the insert tube portion 21.

[0045] Further, according to the water supply tube 20 of the embodiment, the state in which layers of cooling

water having different temperatures exist separately in the insert tube portion 21 can easily be avoided, as will be described below.

[0046] For example, when low-temperature cooling water is supplied, with a small flow rate, from outside the steam generator 1 into the water supply tube 20 with high-temperature cooling water remaining therein, or when high-temperature cooling water flows into the water supply tube 20 from the space 40 outside the water supply tube 20, thermal stratification is generated in which layers of low-temperature cooling water and high-temperature cooling water separately exist. The thermal stratification thus generated is likely to remain longer in the insert tube portion 21 of the water supply tube including the insert tube portion 21 and the ring tube portion 23 horizontally extending in the same height.

[0047] According to the water supply tube 20 of the embodiment, when low-temperature cooling water is supplied, with a small flow rate, from outside the steam generator 1 into the water supply tube 20 with high-temperature cooling water remaining therein, the insert tube portion 21 is rapidly filled with the cooling water supplied from outside, generating the effluence of the high-temperature cooling water in the insert tube portion 21 from the connection tube portion 24 to the upper ring tube portion 232 and the horizontal ring tube portion 231. In this manner, the water supply tube 20 according to the embodiment eliminates the thermal stratification in the insert tube portion 21 in a short period of time compared to the supply tube including the insert tube portion 21 and the ring tube portion 23 horizontally extending in the same height.

[0048] In the embodiment, the tubular passage 234a formed in the upper horizontal tube portion 234 corresponds to the tubular passage between the first tilted portion and the second tilted portion. Further, in the embodiment, the bottom end 234b of the cross section, perpendicular to the flow direction of the cooling water, of the entire section of the tubular passage 234a is arranged vertically higher than the horizontal plane 30. However, the present invention is not limited to the configuration. Any configuration is allowed as long as the bottom end 234b of the cross section, perpendicular to the flow direction of the cooling water, of the tubular passage 234a is arranged vertically higher than the horizontal plane 30 in at least a portion of the section, along the flow direction, of the tubular passage 234a.

[0049] As a water supply tube capable of suppressing thermal stratification in the insert tube portion 21, a water supply tube 120 formed such that the whole ring tube portion 123 is raised than the insert tube portion 21 as illustrated in FIG. 5 and FIG. 6 can be used. FIG. 5 is a cross sectional view illustrating an example of the water supply tube capable of suppressing thermal stratification in an insert tube portion. FIG. 6 is a perspective view illustrating an example of the water supply tube capable of suppressing thermal stratification in an insert tube portion. The ring tube portion 123 of the water supply tube

120 does not include the tilted tube portion 233 as in the embodiment. As illustrated in FIG. 5, in the tubular passage 123a formed in the ring tube portion 123, the vertical location of the top end 123b of the cross section perpendicular to the flow direction of the cooling water is the same at any location in the flow direction of the cooling water. That is, at any location in the flow direction of the cooling water, the top end 123b of the cross section, perpendicular to the flow direction of the cooling water, of the tubular passage 123a is on the same horizontal plane.

[0050] As illustrated in FIG. 6, the ring tube portion 123 includes a tapered portion 123c. The tapered portion 123c is formed in the vicinity of the connection between the ring tube portion 123 and the connection tube portion 124. The tapered portion 123c is formed on both sides, in the circumferential direction, of the connection between the ring tube portion 123 and the connection tube portion 124. The tapered portion 123c has a tapered shape in which the diameter is smaller for a location farther from the connection tube portion 124 along the flow direction of the cooling water in the ring tube portion 123. In the tapered portion 123c, the flow area of the tubular passage 123a gradually decreases as the cross section is distanced from the connection tube portion 124. In the ring tube portion 123, in accordance with both ends of the tapered portion 123c having different diameters, the diameter of the ring-side connection tube portion 123d, which is arranged closer to the connection tube portion 124 than the tapered portion 123c, is larger than the diameter of the portion 123e which is arranged farther from the connection tube portion 124 than the tapered portion 123c. The connection tube portion 124 is similar to the connection tube portion 24 of the water supply tube 20 and is tilted so that the side having the greater distance from the insert tube portion 21 along the flow direction of the cooling water is located vertically higher than the side having the smaller distance from the insert tube portion 21.

[0051] The ring-side connection tube portion 123d is a linear tubular portion having a constant diameter. As illustrated in FIG. 5, the bottom end 123f of the cross section, perpendicular to the flow direction of the cooling water, of the ring-side connection tube portion 123d is located vertically higher than the top end 21a of the inner wall surface of the insert tube portion 21 at the connection between the insert tube portion 21 and the connection tube portion 124.

[0052] The water supply tube 120 can also suppress the generation of thermal stratification in the insert tube portion 21 or rapidly eliminate the thermal stratification, thereby suppressing generation of thermal stress causing fatigue. However, when the whole ring tube portion 123 is raised against the insert tube portion 21, the ring tube portion 123 is easily exposed to a gas layer when the water level in the steam generator 1 decreases.

[0053] Contrarily, as illustrated in FIG. 3 and FIG. 4, in the water supply tube 20 of the embodiment, the generator internal tube portion 22 is bent to raise itself against

the insert tube portion 21 at the connection tube portion 24, and then bent to lower itself at the tilted tube portion 233. In this manner, the vertical location of the horizontal ring tube portion 231 is lowered, thereby suppressing exposure of the horizontal ring tube portion 231 above the surface of the cooling water. As illustrated in FIG. 2, the top end 231b of the cross section, perpendicular to the flow direction of the cooling water, of the tubular passage 231a in the horizontal ring tube portion 231 is located vertically lower than the horizontal plane 30 including the top end 21a of the inner wall surface of the insert tube portion 21 at the connection between the insert tube portion 21 and the connection tube portion 24. Configured in this manner, the tubular passage 231a in the horizontal ring tube portion 231 is kept below the water level even when the cooling water level in the steam generator 1 is low enough to start exposing the insert tube portion 21. By lowering chances of the horizontal ring tube portion 231 exposed above the cooling water, the generation of a steam-pocket in the tubular passage 231a can be suppressed.

[0054] The vertical location of the tubular passage 231a formed in the horizontal ring tube portion 231 is not limited to the configuration described above. Any vertical location can be determined. For example, in the embodiment, the top end 231b of the cross section, perpendicular to the flow direction of the cooling water, of the tubular passage 231a is located vertically lower than the central axis X of the insert tube portion 21. Configured in such manner, in the water supply tube 20 of the embodiment, any vertical location of the tubular passage 231a in the horizontal ring tube portion 231 can be determined, maintaining the effect of suppressing thermal stratification in the insert tube portion 21.

[0055] Further, in the embodiment, the upper horizontal tube portion 234 is provided with an effluence tube 251 (25). This configuration suppresses suction of the cooling water in the insert tube portion 21 out into the horizontal ring tube portion 231 side when the cooling water level in the steam generator 1 decreases. For example, in a configuration without the effluence tube 251 provided on the upper horizontal tube portion 234, when the cooling water level is low enough to start exposing the horizontal ring tube portion 231, and when the supply of the cooling water from outside to the water supply tube 20 is stopped, the cooling water in the insert tube portion 21 located higher than the horizontal ring tube portion 231 may be suctioned out into the horizontal ring tube portion 231 side. In the embodiment, the effluence tube 251 provided on the upper horizontal tube portion 234 is exposed when the cooling water level in the steam generator 1 decreases, thereby opening the tubular passage 234a. In this manner, the suction of the cooling water in the insert tube portion 21 out into the horizontal ring tube portion 231 is suppressed.

[0056] Note that, the vertical location of the horizontal ring tube portion 231 can be determined based on the predetermined target for controlling the water level of the

cooling water in the space 40 in the steam generator 1. The target water level of the cooling water is determined depending on a control parameter of a nuclear plant including the steam generator 1. For example, when a lower limit is determined for the target of the water level to be controlled, it may be configured that the top end 231b of the cross section, perpendicular to the flow direction of the cooling water, of the tubular passage 231a is located vertically lower than the lower limit of the water level. Configured in this manner, as long as the cooling water level in the steam generator 1 is at, or higher than, the lower limit of the target water level, the tubular passage 231a is kept below the surface of the cooling water. Thereby, the generation of a steam-pocket in the tubular passage 231a is suppressed.

[0057] Further, the vertical location of the horizontal ring tube portion 231 may be determined so that, for example, the tubular passage 231a in the horizontal ring tube portion 231 is located below the cooling water level in the space 40 in the steam generator 1 even when a supplied flow rate of low-temperature cooling water is small, as in the start-up or shutdown under a hot state in a plant.

[0058] In the embodiment, the tube portion including the effluence tube 25 is provided as the ring tube portion 23 extending in a ring shape. However, the shape of the tube portion including the effluence tube 25 is not limited to such configuration.

Reference Signs List

[0059]

1	steam generator
2	body portion
11	nozzle
112	penetration hole
20	water supply tube
21	insert tube portion
22	generator internal tube portion
23	ring tube portion
231	horizontal ring tube portion
232	upper ring tube portion
233	tilted tube portion
234	upper horizontal tube portion
24	connection tube portion
25	effluence tube
30	horizontal plane

Claims

1. A water supply tube for a steam generator comprising:

an insert tube portion horizontally extending and configured to be inserted in a penetration hole penetrating a shell member of the steam gener-

ator; and

a generator internal tube portion connected to the insert tube portion and arranged inside the steam generator,

wherein the generator internal tube portion includes a tubular passage formed in an axial direction of the generator internal tube portion and an effluence unit allowing effluence of cooling water in the tubular passage from the tubular passage to a space in the steam generator, the tubular passage allowing cooling water supplied from outside the steam generator via the insert tube portion to flow in the tubular passage, wherein the tubular passage includes a first tilted portion which is tilted so that a side having a greater distance from the insert tube portion along a flow direction of cooling water is located vertically higher than a side having a smaller distance from the insert tube portion and a second tilted portion which is located with a greater distance from the insert tube portion along the flow direction than the first tilted portion and is tilted so that a side having a greater distance from the insert tube portion along the flow direction is located vertically lower than a side having a smaller distance from the insert tube portion, and wherein, in at least a portion of a section, along the flow direction, of the tubular passage between the first tilted portion and the second tilted portion, a bottom end of a cross section, perpendicular to the flow direction, of the tubular passage is arranged vertically higher than a horizontal plane including a top end of an inner wall surface of the insert tube portion at a connection between the insert tube portion and the generator internal tube portion.

2. The water supply tube for a steam generator according to claim 1, wherein the effluence unit is not included in a section, of the generator internal tube portion, in which the first tilted portion is formed.
3. The water supply tube for a steam generator according to claim 1, wherein the generator internal tube portion includes a ring tube portion extending in a ring shape along an inner circumferential surface of the shell member and a connection tube portion branching off from the ring tube portion to connect the ring tube portion and the insert tube portion, wherein the first tilted portion is provided as the tubular passage formed in the connection tube portion, and wherein the second tilted portion is provided as the tubular passage formed in the ring tube portion, the second tilted portion being formed on each of both ends, in an axial direction, of the ring tube portion with the connection tube portion in between.

4. The water supply tube for a steam generator according to claim 3, wherein a horizontal ring tubular passage which is the tubular passage extending in a horizontal direction is formed in a portion, arranged farther than the second tilted portion from the insert tube portion along the flow direction, of the ring tube portion, and

wherein a top end of a cross section, perpendicular to the flow direction, of the horizontal ring tubular passage is provided vertically lower than the horizontal plane including the top end of the inner wall surface of the insert tube portion at the connection between the insert tube portion and the generator internal tube portion.

5. The water supply tube for a steam generator according to claim 3, wherein a horizontal ring tubular passage which is the tubular passage extending in a horizontal direction is formed in a portion, arranged farther than the second tilted portion from the insert tube portion along the flow direction, of the ring tube portion, and wherein a top end of a cross section, perpendicular to the flow direction, of the horizontal ring tubular passage is arranged vertically lower than a lower limit of a target for controlling a water level of cooling water in the space in the steam generator.

FIG.1

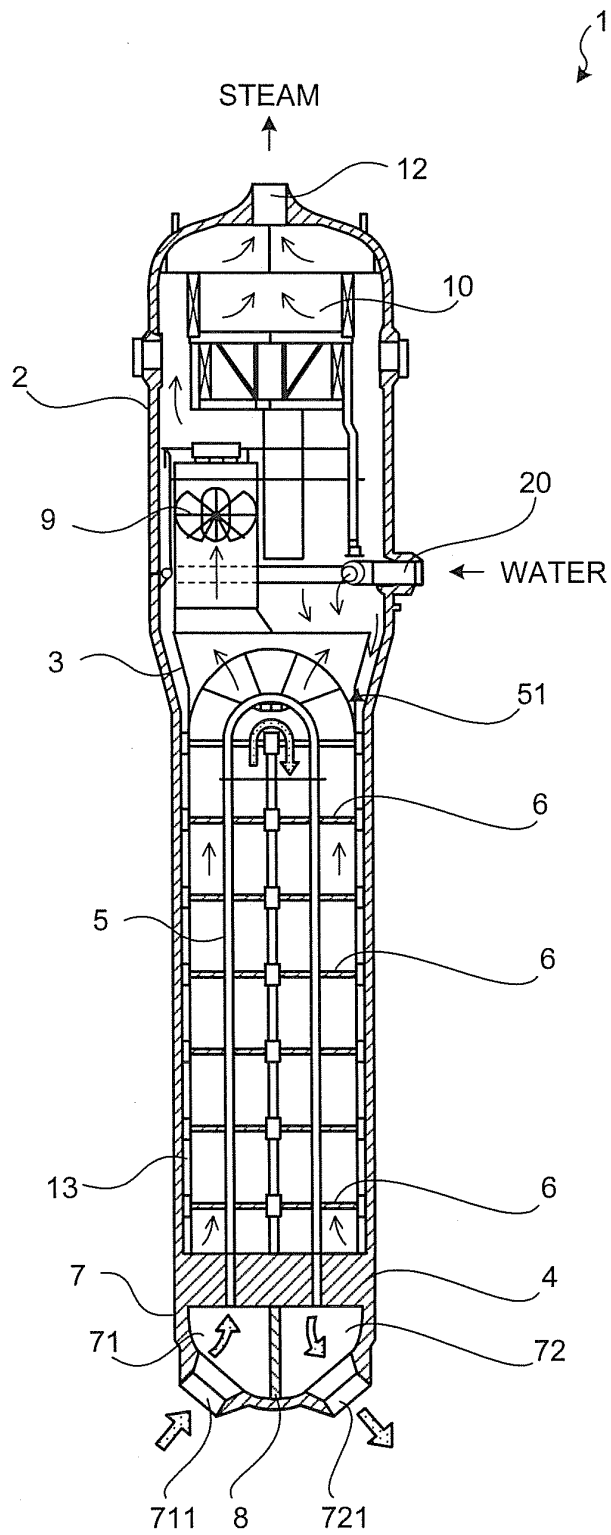


FIG.2

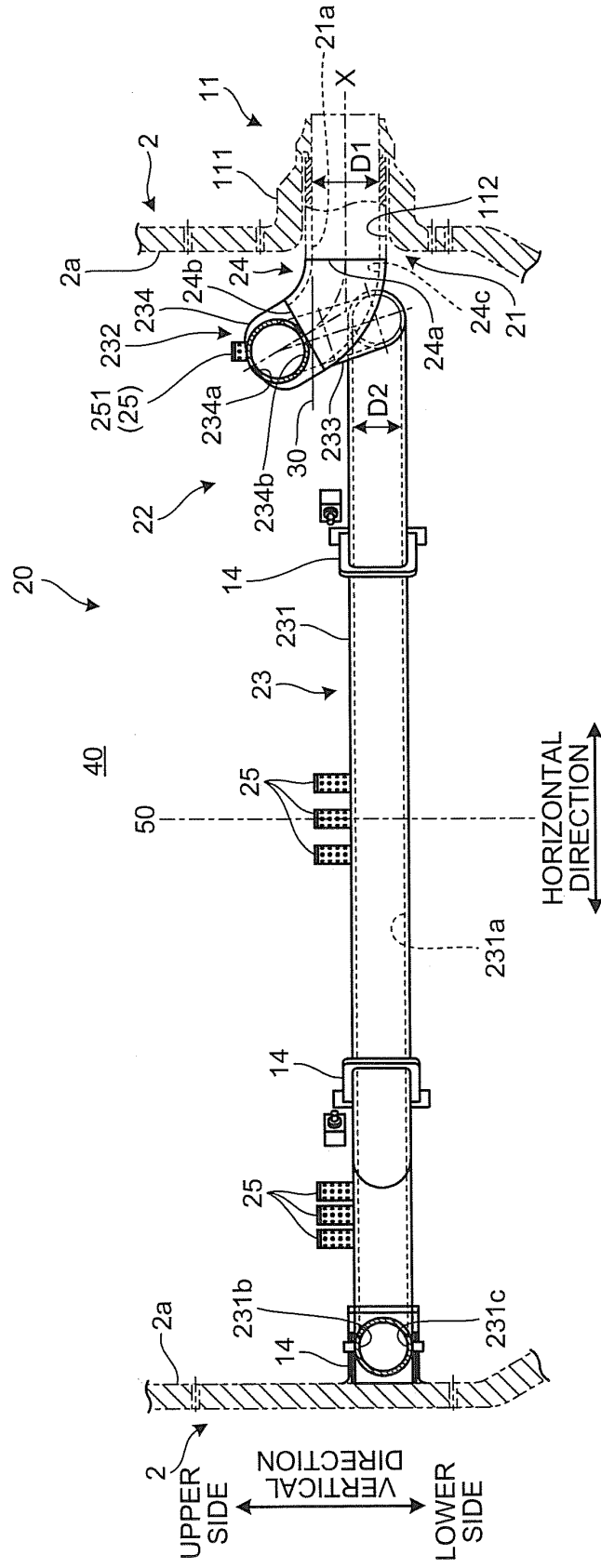


FIG.3

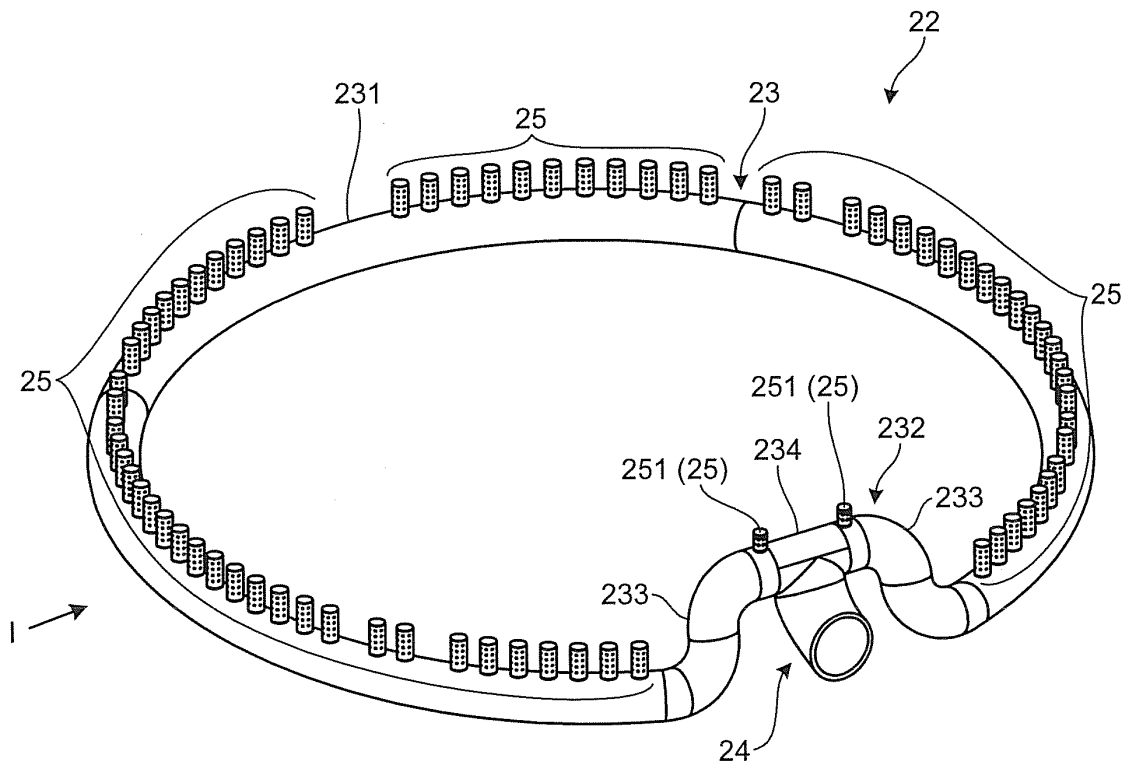


FIG.4

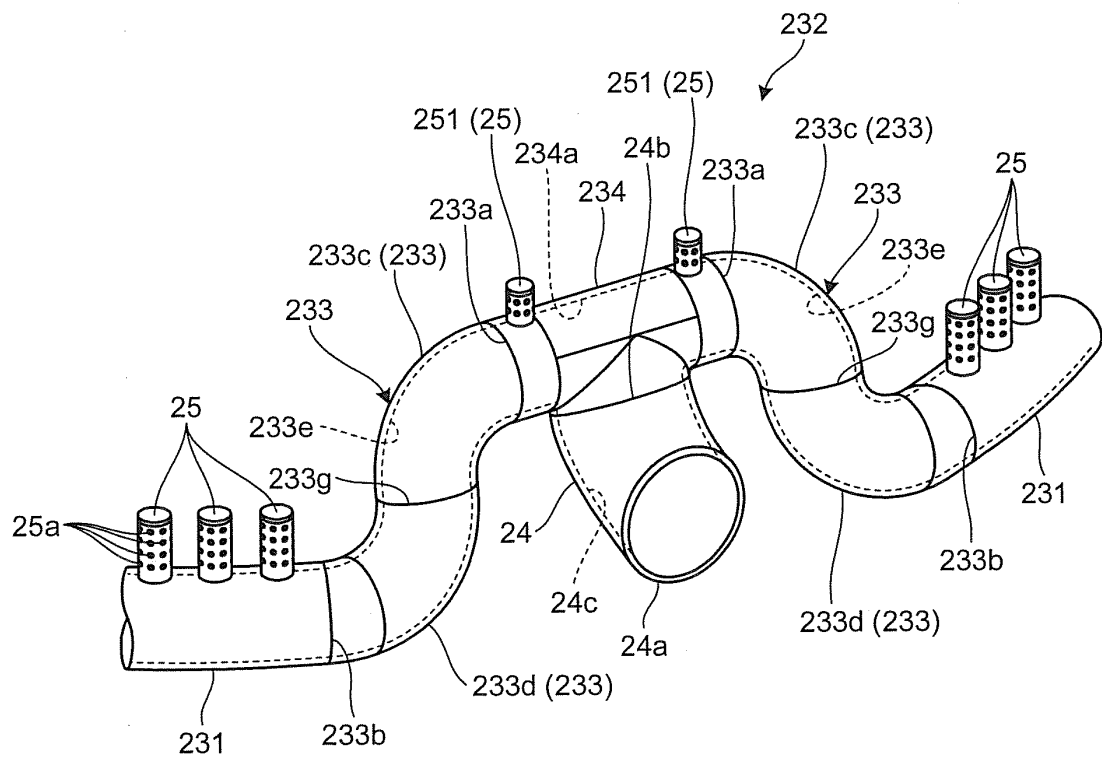


FIG.5

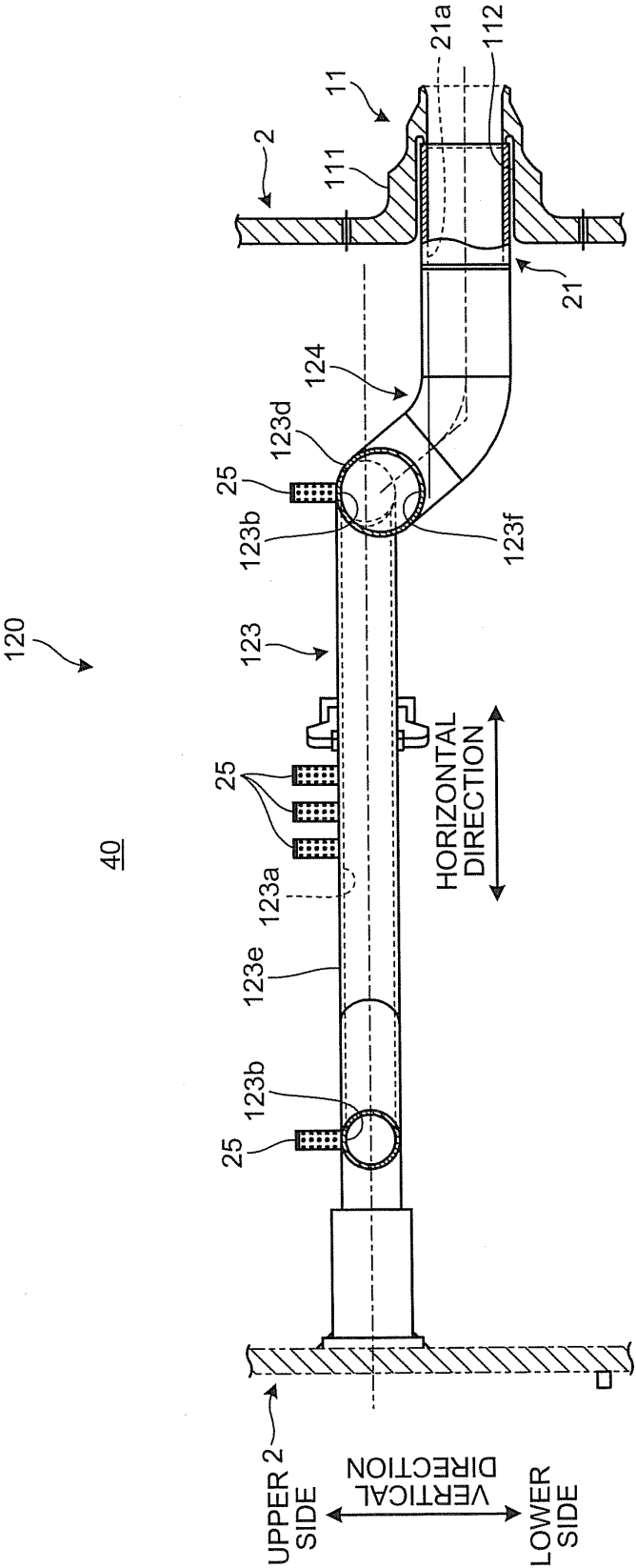
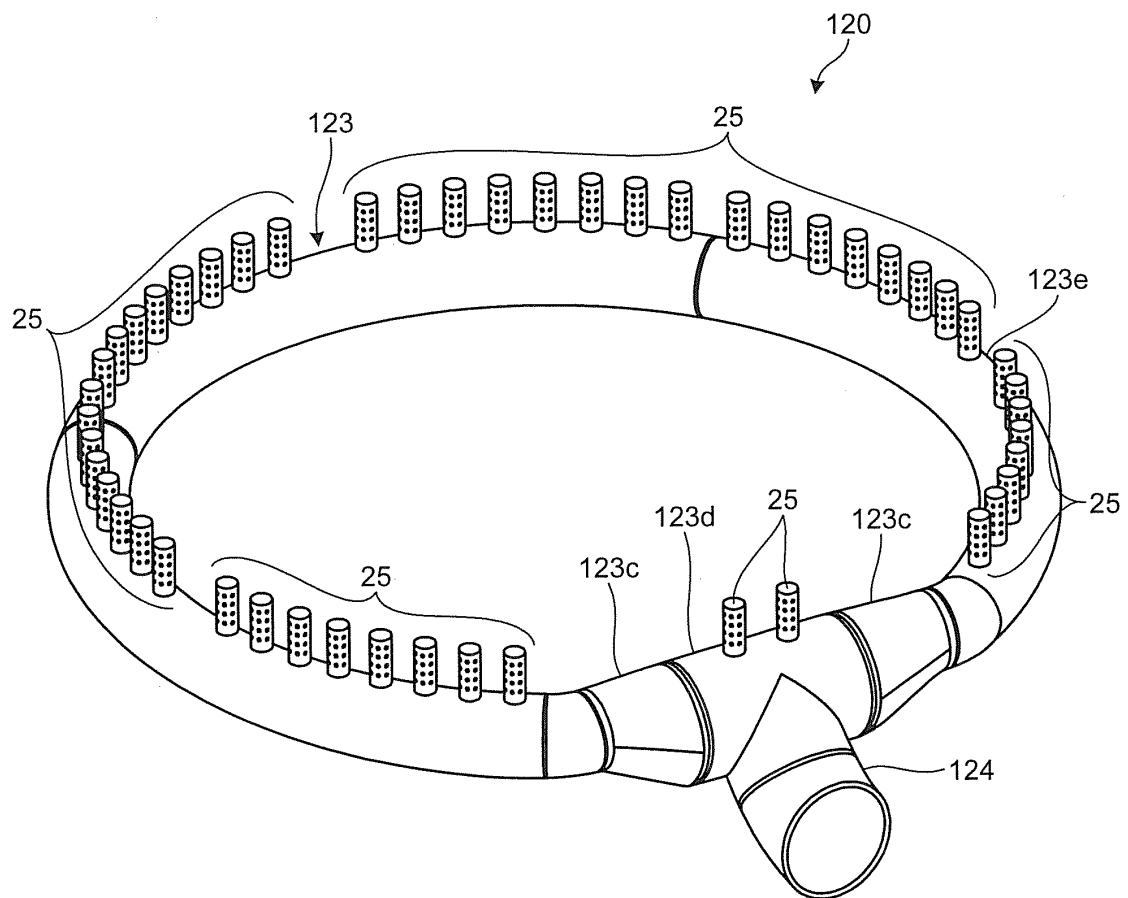


FIG.6



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/052501

A. CLASSIFICATION OF SUBJECT MATTER

G21D1/00(2006.01) i, F17D1/08(2006.01) i, F22B1/16(2006.01) i, F22B37/00(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)

G21D1/00, F17D1/08, F22B1/16, F22B37/00

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 1996-2013

Kokai Jitsuyo Shinan Koho 1971-2013 Toroku Jitsuyo Shinan Koho 1994-2013

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.
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 56/1988 (Laid-open No. 106710/1989) (Mitsubishi Heavy Industries, Ltd.), 18 July 1989 (18.07.1989), entire text; all drawings (Family: none)	1-5
A	JP 2003-28977 A (Mitsubishi Heavy Industries, Ltd.), 29 January 2003 (29.01.2003), entire text; all drawings (Family: none)	1-5

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

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Date of the actual completion of the international search
15 April, 2013 (15.04.13)Date of mailing of the international search report
23 April, 2013 (23.04.13)Name and mailing address of the ISA/
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/052501

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 33613/1981 (Laid-open No. 150390/1982) (Mitsubishi Heavy Industries, Ltd.), 21 September 1982 (21.09.1982), entire text; all drawings (Family: none)	1-5

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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