United States Patent [19]

Porter et al.

[11] **3,848,430**

[45] **Nov. 19, 1974**

[54] **ABSORPTION REFRIGERATION MACHINE WITH SECOND STAGE GENERATOR**

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[73] Assignee: **The Trane Company,** La Crosse, Wis.

[22] Filed: **Sept. 13, 1973**

[21] Appl. No.: **397,090**

[52] **U.S. Cl.** **62/476,** 62/497, 165/82, 165/162

[51] **Int. Cl.** **F25b 15/06**

[58] **Field of Search** 62/476, 497; 165/82, 162, 165/81

[56] **References Cited**

UNITED STATES PATENTS

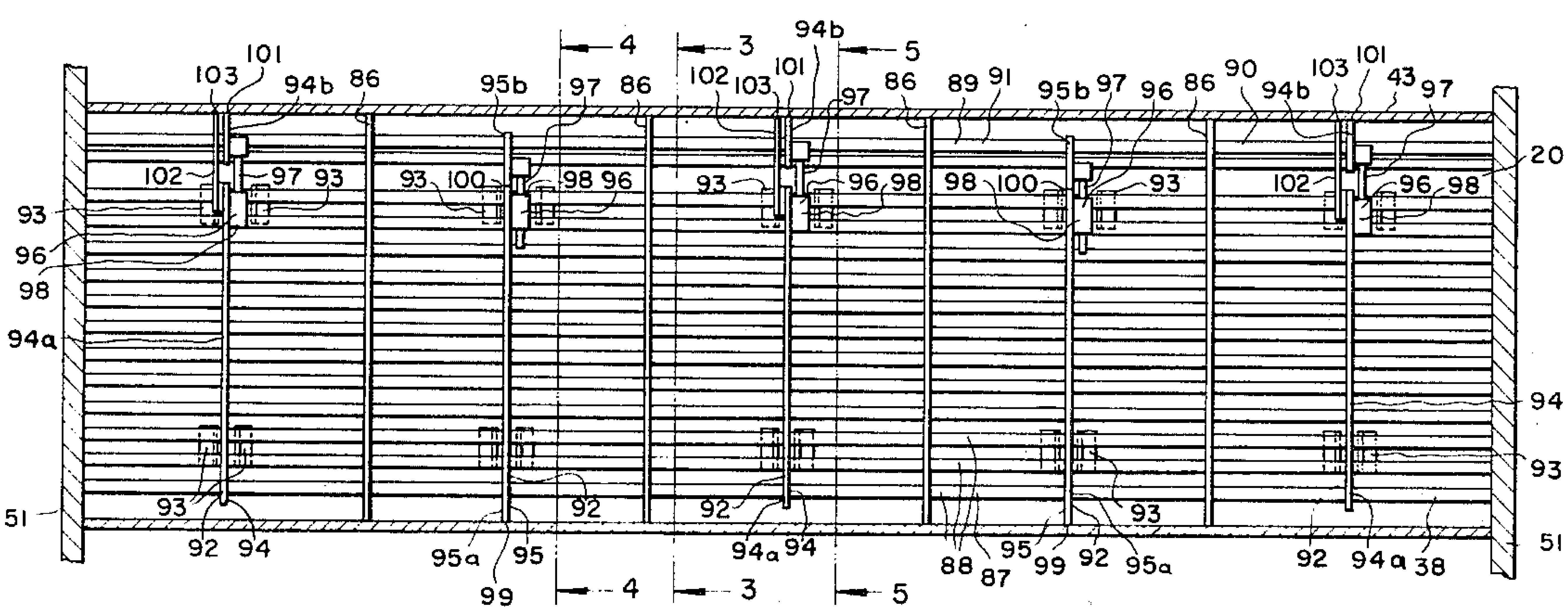
1,992,504	2/1935	Penniman	165/162 X
3,012,761	12/1961	Gardner et al.	165/162 X
3,212,570	10/1965	Holman	165/162
3,550,394	12/1970	Peckham	62/497 X
3,659,431	5/1972	Iwasawa	62/476

Primary Examiner—William F. O'Dea
Assistant Examiner—Peter D. Ferguson

[57] **ABSTRACT**

An absorption refrigeration machine having a second stage generator which utilizes heat from the first stage generator high pressure steam condensate and heat from the vapor generated in the first stage to heat intermediate strength absorbent solution in the second stage generator wherein expansion relieving means are provided in said second stage generator.

11 Claims, 12 Drawing Figures



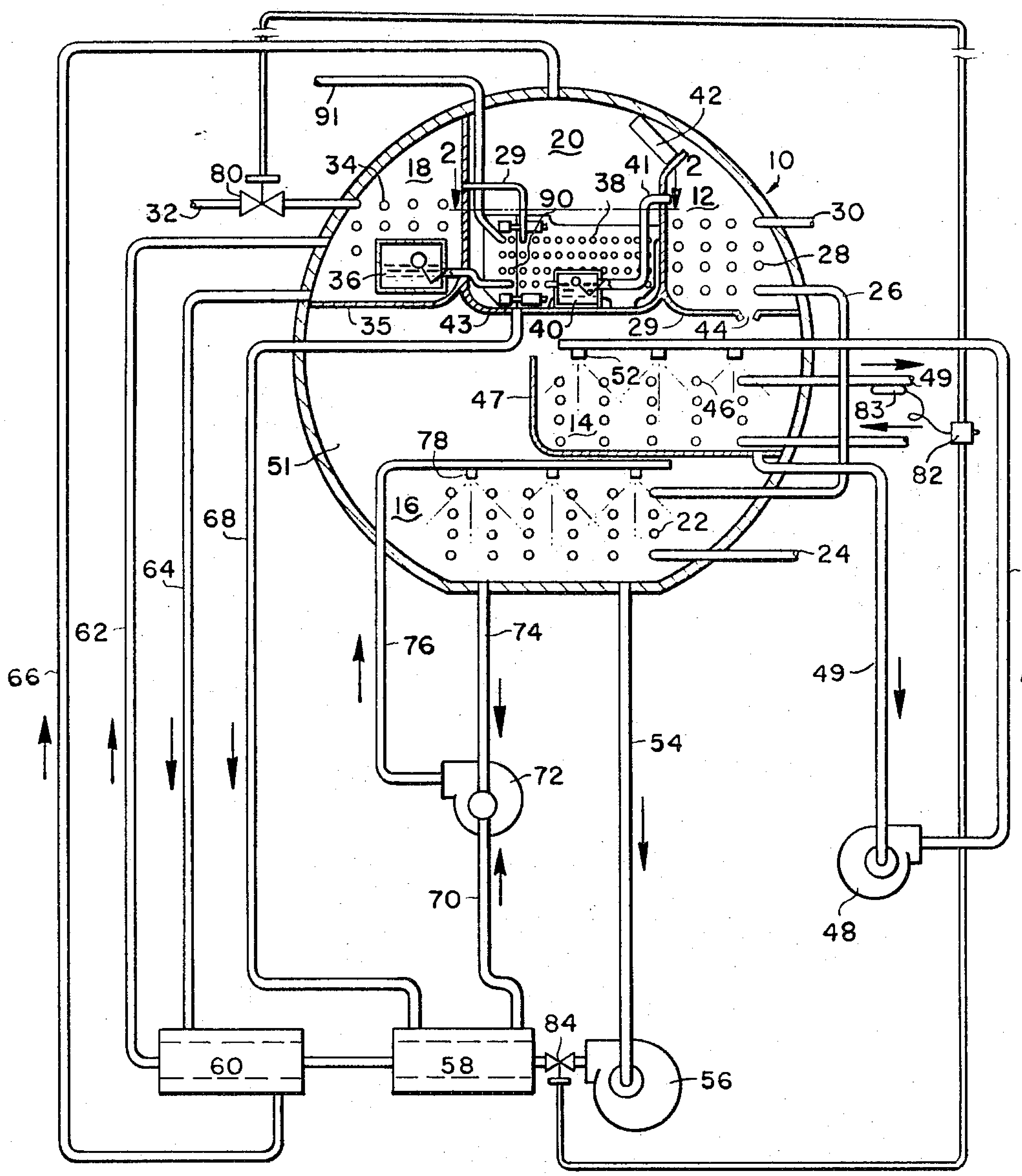

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FIG. 1

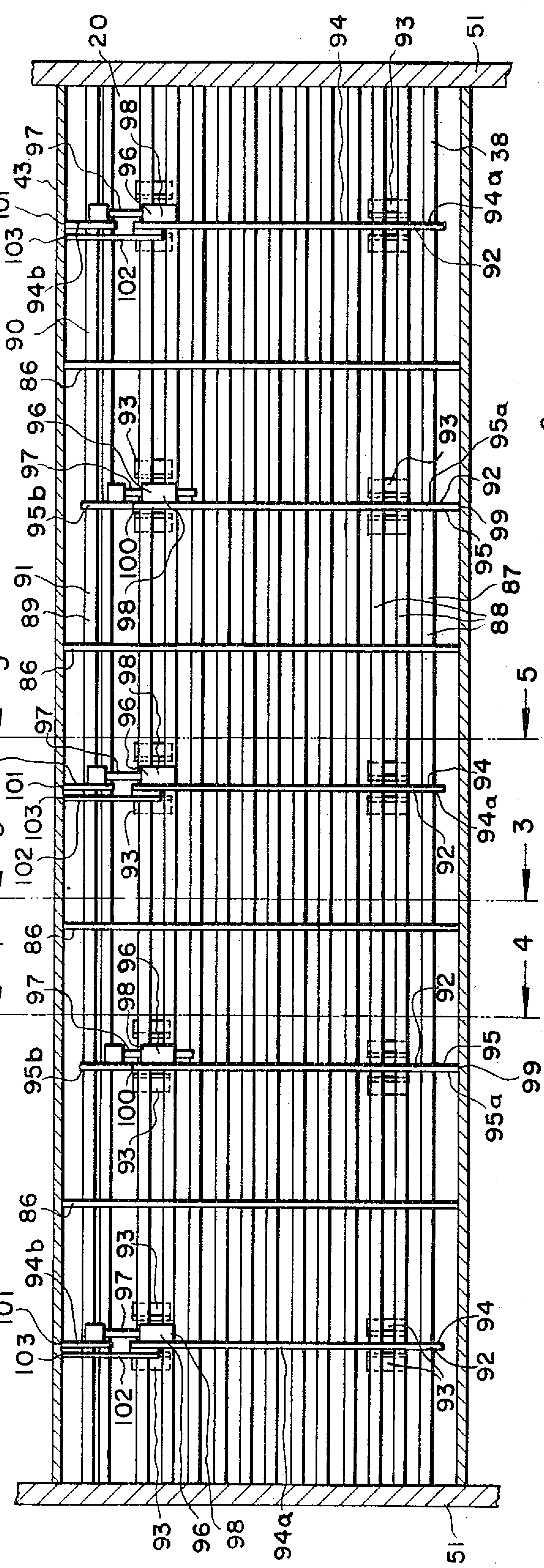

FIG. 2

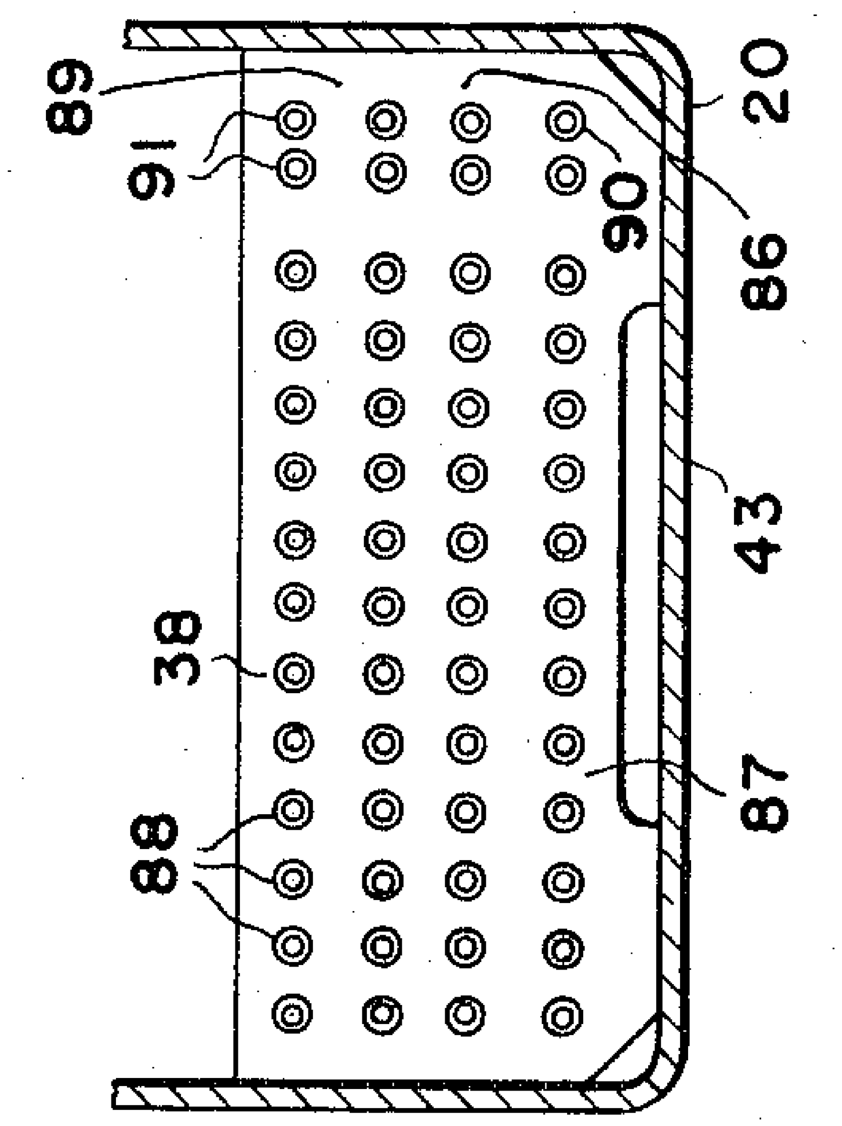

FIG. 3

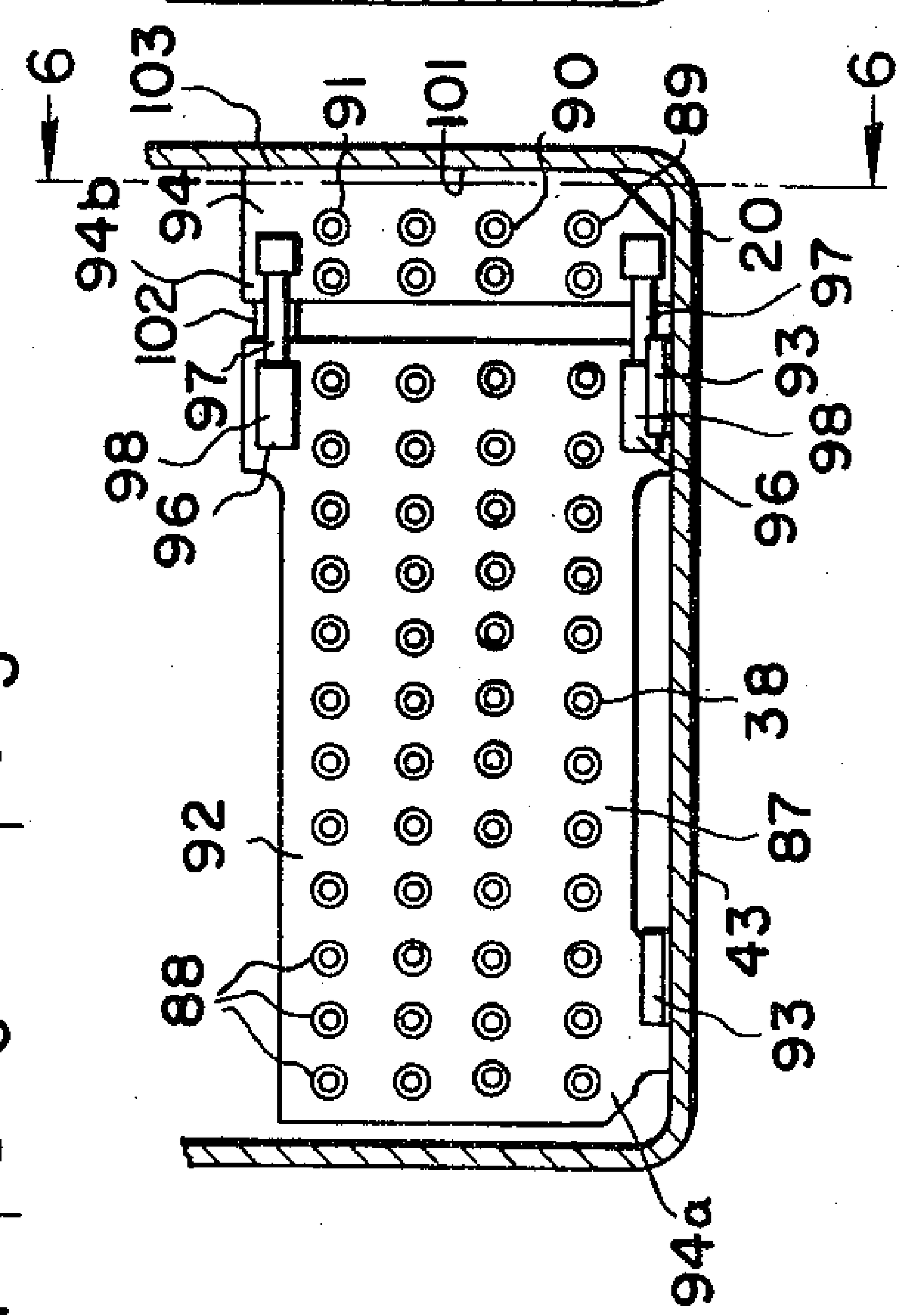

FIG. 5

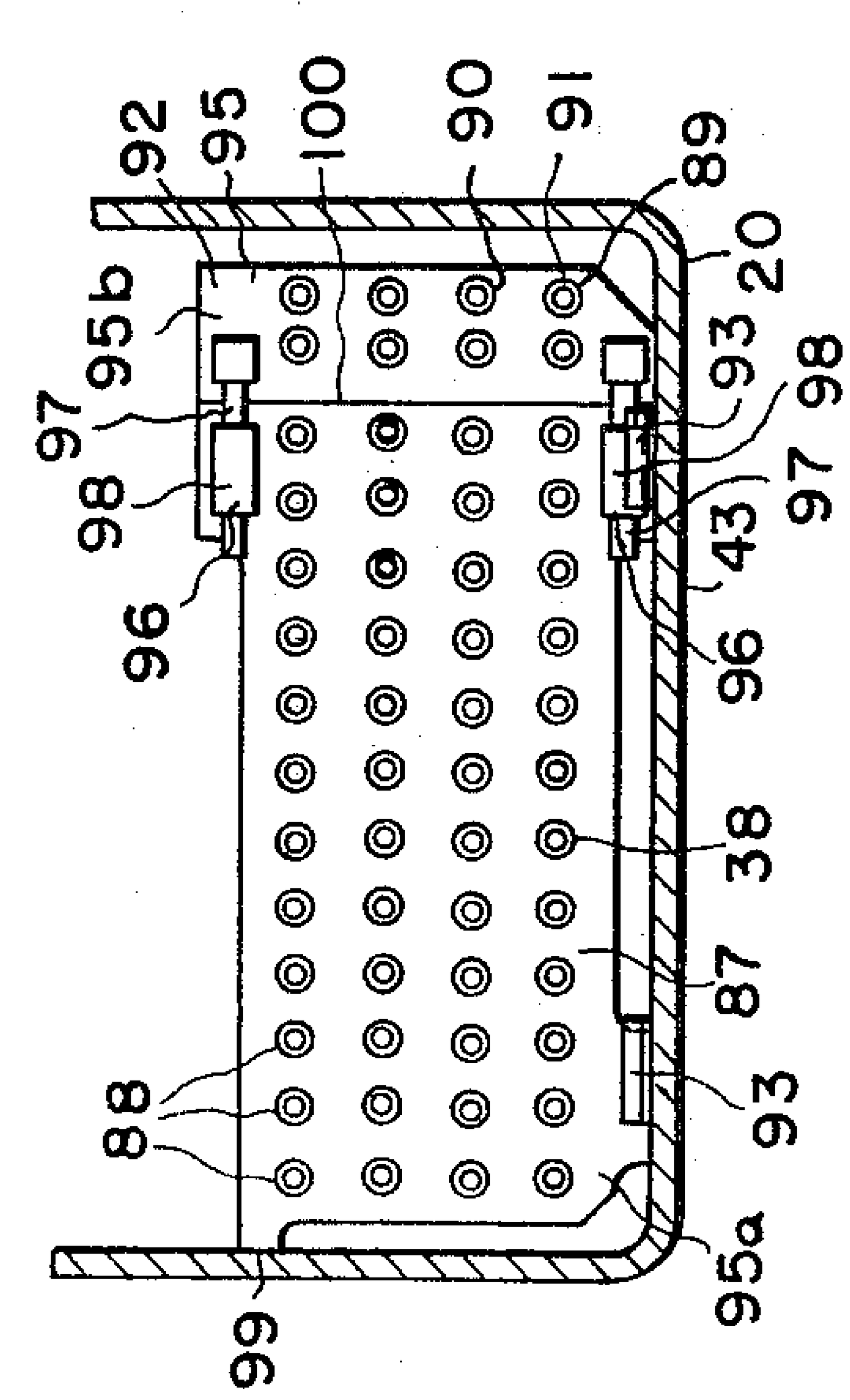

FIG. 4

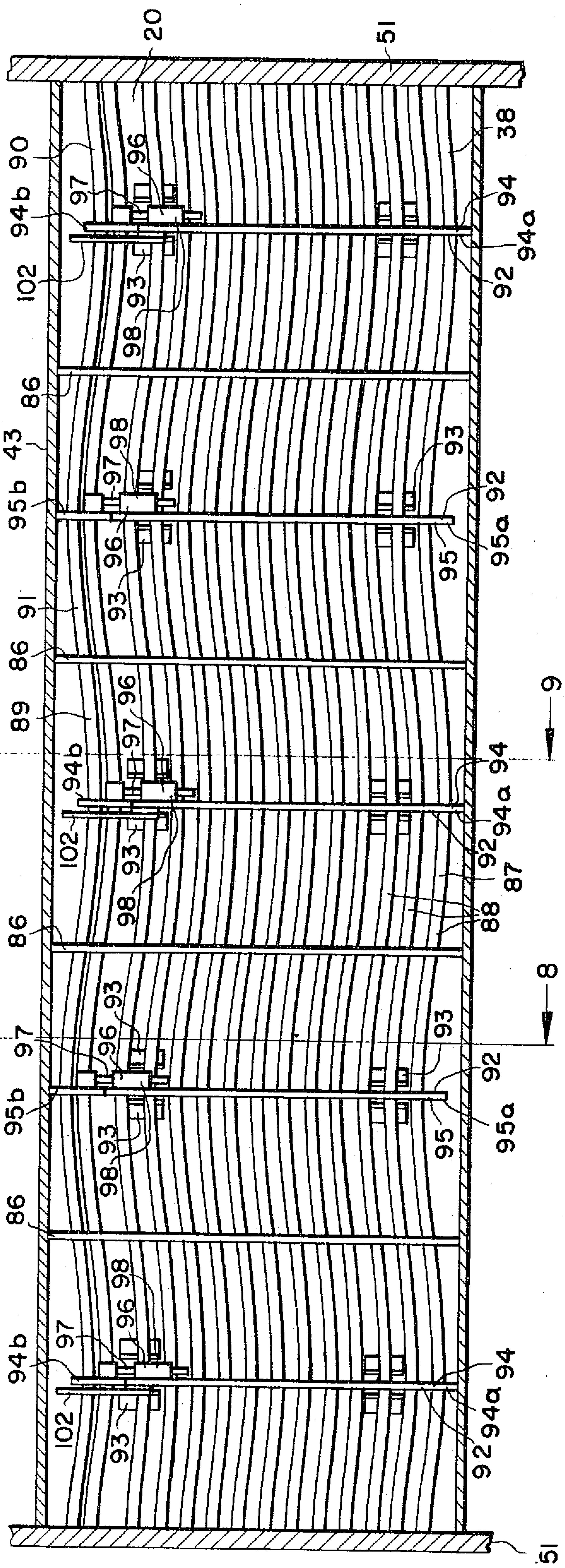

FIG. 7

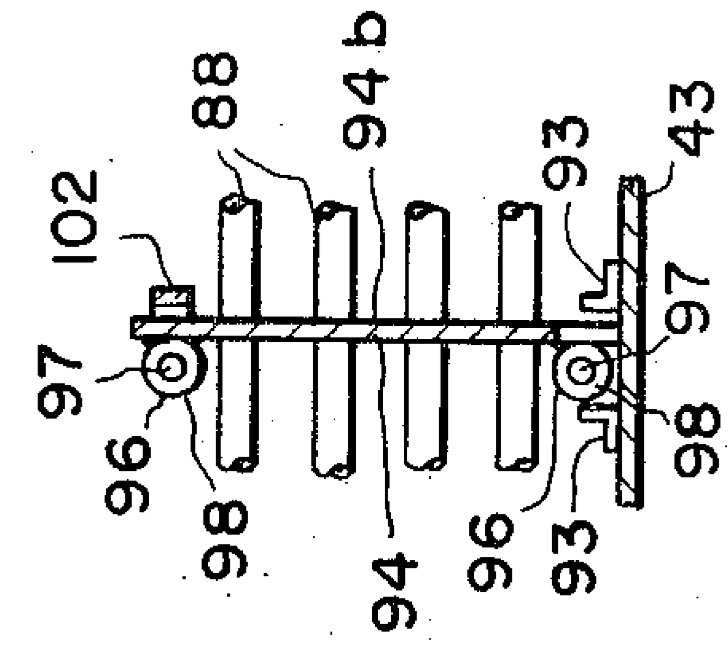

FIG. 6

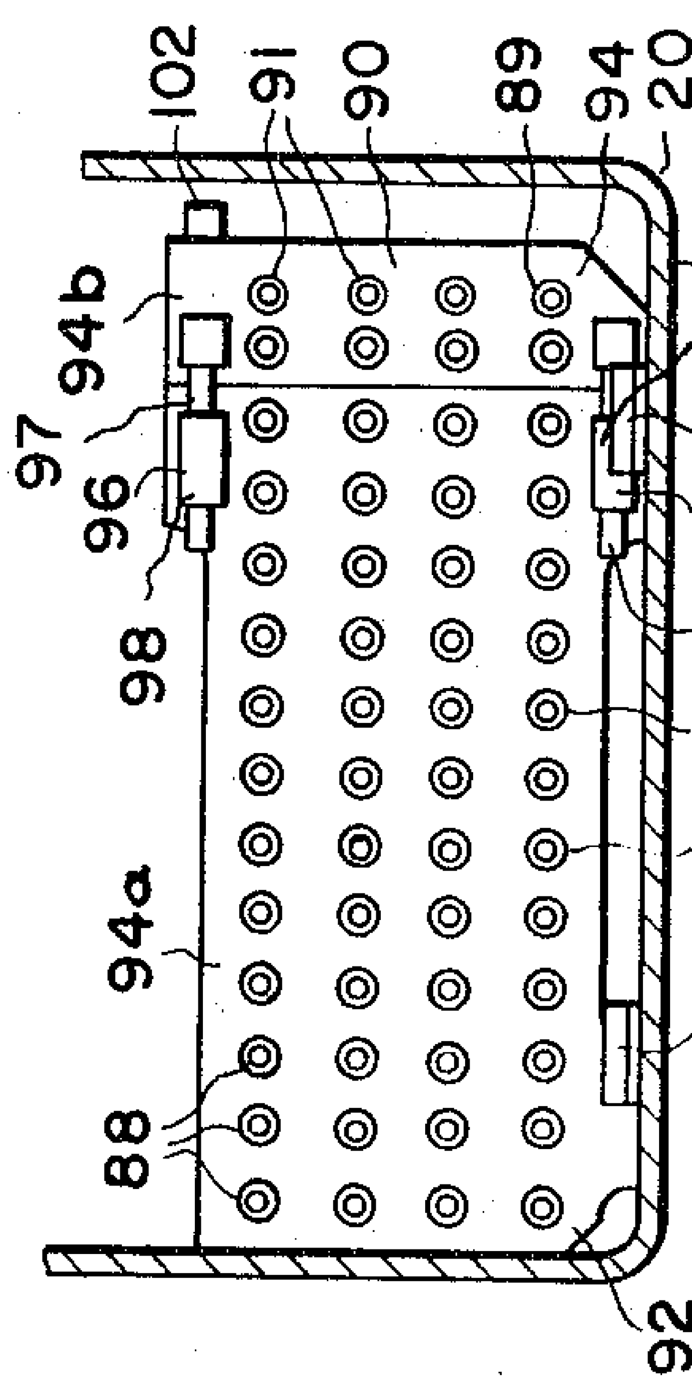

FIG. 9

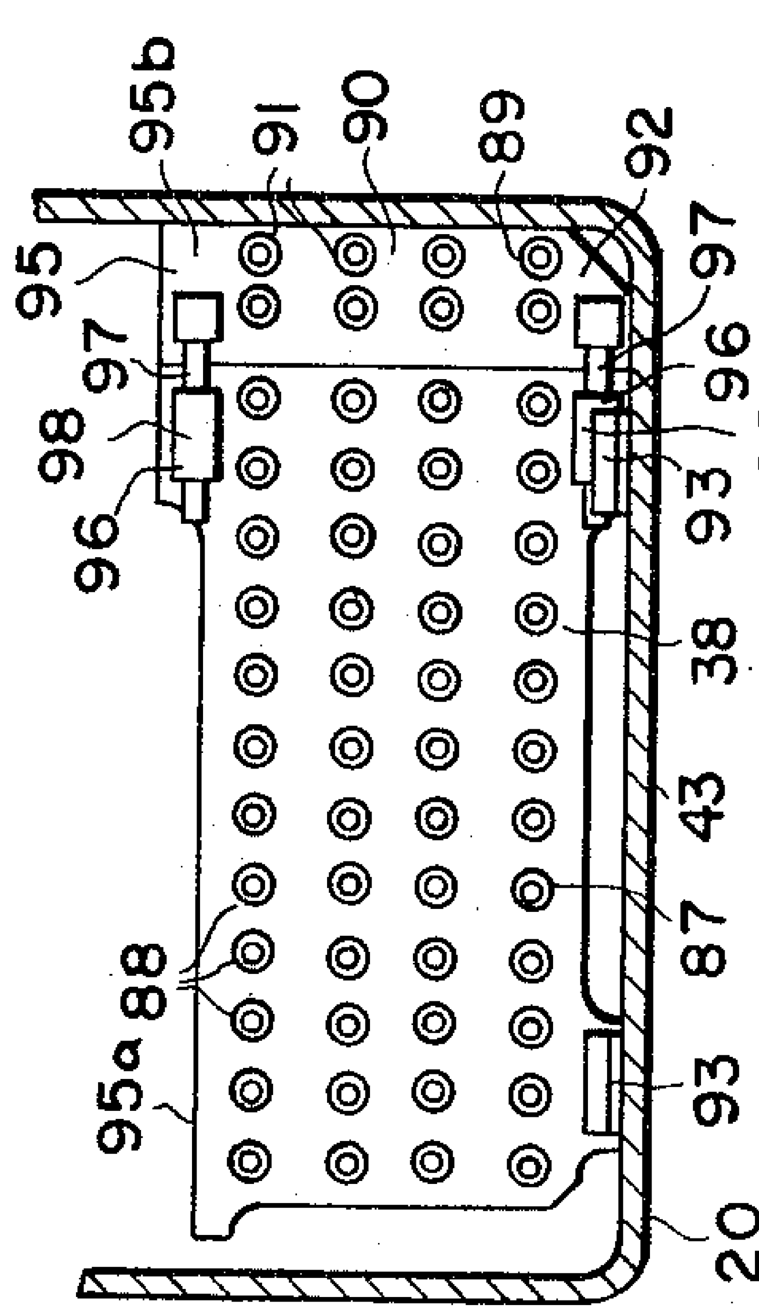

FIG. 8

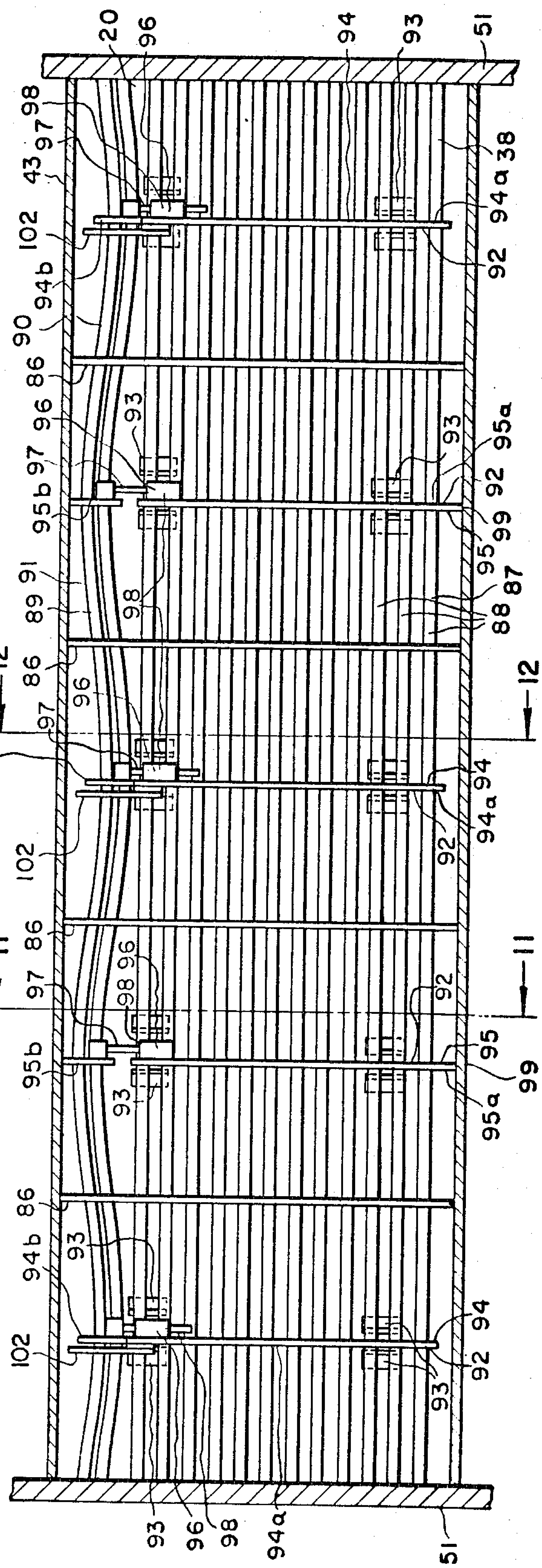

FIG. 10

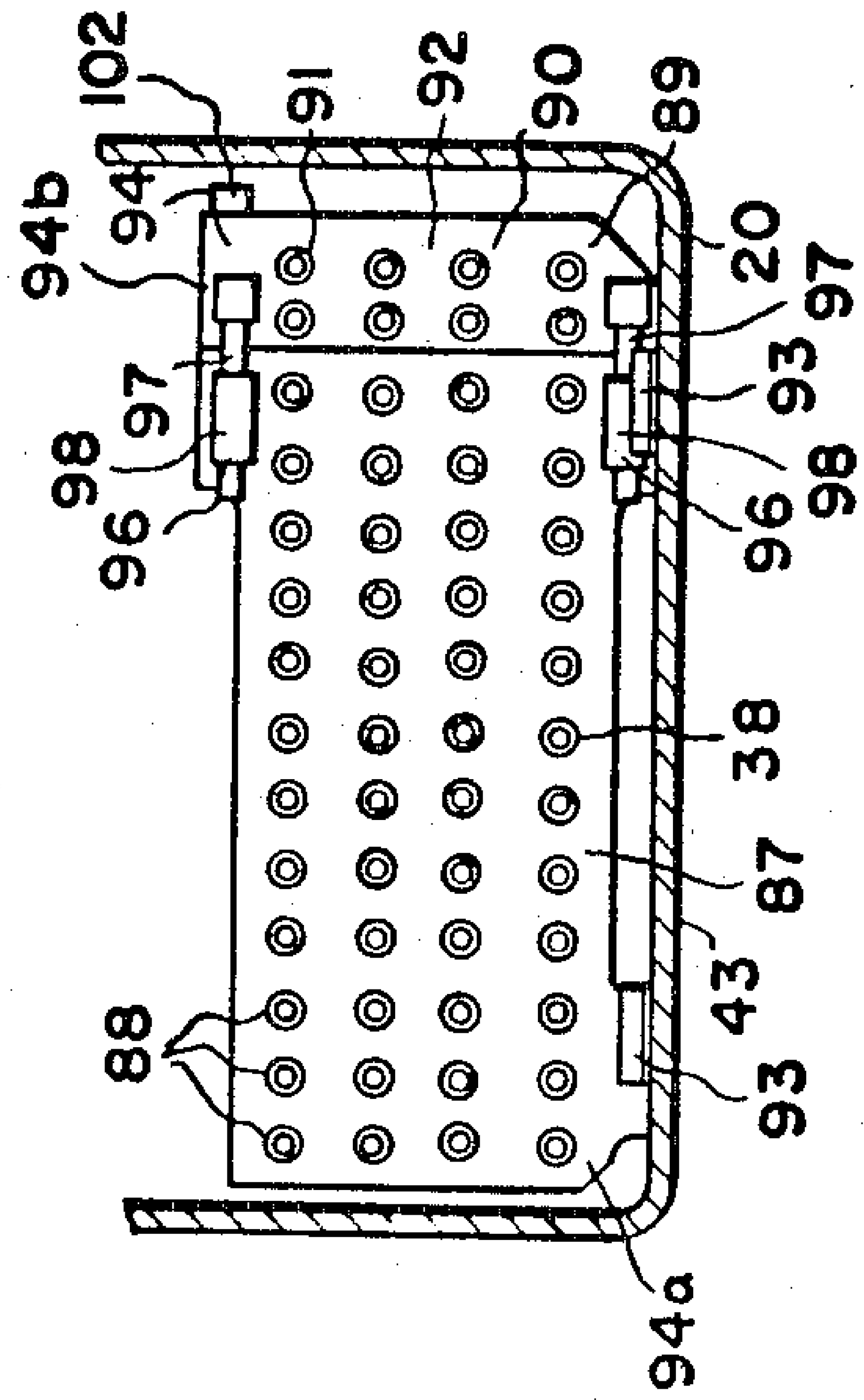

FIG. 12

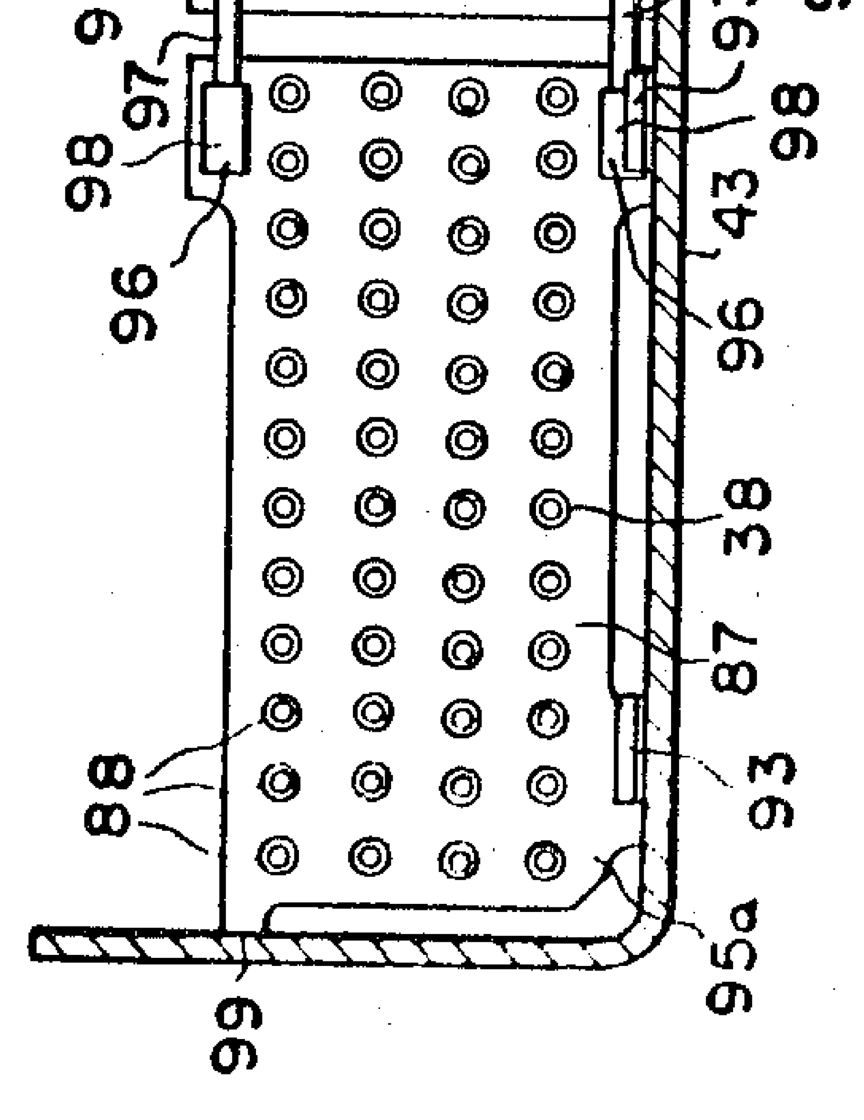

FIG. 11

ABSORPTION REFRIGERATION MACHINE WITH SECOND STAGE GENERATOR

BACKGROUND OF INVENTION

This invention relates to absorption refrigeration machines having a two stage generator such as shown and described in U.S. Pat. No. 3,550,394. Further, this invention relates to a second stage generator which employs expansion relieving means shown and described in U.S. Pat. No. 3,212,570. More particularly this invention relates to the discovery of and solution to certain problems relating to second stage generator tube wear and reliability.

An absorption refrigeration machine of the type shown in U.S. Pat. No. 3,550,394 was built and operated. Design of the second stage generator incorporated the principles of U.S. Pat. No. 3,212,570. However, after some period of operation it was found that tubes carrying steam condensate in the second stage generator would fail. The reasons for these premature failures are not fully understood nor were these failures anticipated because both the condensate and the vapor carrying tubes of the second stage generator were operated at nearly the same temperature. However, in retrospect it is surmised that the steam condensate tubes were being heated at some time to temperatures substantially higher than the vapor conducting tubes. This could possibly occur in the event of leaking of the high pressure steam control valve or could possibly be a transient condition of start up.

SUMMARY OF THE INVENTION

This invention encompasses the discovery of certain problems and the solution thereof relating to absorption refrigeration machines employing second stage generators. More particularly, this invention pertains to the discovery that tube failures of the condensate tubes will occur despite tube expansion relieving means unless further means are provided to permit longitudinal expansion of condensate tubes relative to vapor tubes. The invention provides means to allow the condensate tubes of the second stage generator to expand longitudinally relative to the vapor tubes especially where the condensate and vapor tubes are constrained to expanding into a wave-like pattern upon elongation.

Specifically this invention involves a two-stage absorption machine wherein the second stage generator is heated by water vapor generated in the first stage generator and water condensate formed in the first stage generator from heating steam supplied through a steam control valve, a second stage generator comprising: a shell defining an enclosure; first conduit means for passing an absorption solution from said first stage generator into said enclosure, a first elongated tube bundle of first tubes extending through said enclosure; a second elongated tube bundle of second tubes extending through said enclosure; second conduit means for passing water vapor that is generated in said first stage generator through said first tubes of first tube bundle; third conduit means for passing steam condensate that is formed in said first stage generator through said second tubes of said second tube bundle; each of said tube bundles being supported by longitudinally spaced alternately fixed and floating tube supports; at least some of said floating tube supports of said second tube bundle being relatively movable with respect to adjacent floating tube supports of said first tube bundle to permit longitudinal expansion of said second tubes of said tube bundle relative to said first tubes of said first tube bundle during idle and start up conditions of said refrigeration machine.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic of an absorption refrigeration machine having a second stage generator incorporating the invention.

FIG. **2** is a horizontal section taken at line **2—2** of FIG. **1** showing the second stage generator when the machine is turned completely off.

FIG. **3** is a vertical section taken at line **3—3** of FIG. **2** showing a fixed tube support.

FIG. **4** is a vertical section taken at line **4—4** of FIG. **2** showing a floating tube support.

FIG. **5** is a vertical section taken at line **5—5** of FIG. **2** showing another floating tube support.

FIG. **6** is a vertical section taken at line **6—6** of FIG. **5** showing a detail of the floating tube support guide means.

FIG. **7** is a view similar to FIG. **2** showing the position of the two tube bundles when heated during operation of the refrigeration machine.

FIG. **8** is a vertical section taken at line **8—8** of FIG. **7**.

FIG. **9** is a vertical section taken at line **9—9** of FIG. **7**.

FIG. **10** is a view similar to FIG. **2** depicting what is thought to be the appearance of the second stage generator during a transient start up condition of the refrigeration machine or a condition which may occur if valve **80** were to leak during periods when the refrigeration machine is otherwise inactive.

FIG. **11** is a vertical section taken at line **11—11** of FIG. **10**.

FIG. **12** is a vertical section taken at line **12—12** of FIG. **10**.

DETAILED DESCRIPTION

Now with reference to FIG. **1** it will be seen that the absorption machine has a fluid tight shell **10** enclosing a condenser **12**, an evaporator **14**, an absorber **16**, a first stage generator **18** and a second stage generator **20**. The refrigeration machine is supplied with high pressure steam through a conduit **32** and cooling water, such as from a cooling tower, through a conduit **24**. Water such as from a building to be chilled is conducted via a conduit to evaporator heat exchanger **46** where such water is cooled and returned via conduit **49** to meet the building cooling load.

For purposes of cooling, pump **48** circulates water via conduit **50** and spray nozzles **52** over heat exchanger **46** where upon a portion of the water is evaporated to cool heat exchanger **46**. The remaining unevaporated water is returned via conduit **49** to pump **48** for recirculation.

Water vapor thus formed in the evaporator is conducted to the absorber **16** where it is absorbed in a solution of lithium bromide and water pumped from pump **72** via conduit **76** to spray nozzles **78**. The heat which is generated during this absorption process is removed from the absorber **16** via heat exchanger **22** supplied with cooling water via conduit **24**. The cooling water is discharged from heat exchanger **22** via conduit **26** to condenser **12**. A portion of the dilute absorbent solution is removed from absorber **16** via conduit **74** to the inlet of pump **72** for admixture with concentrated absorbent solution conducted through conduit **70** whereby an intermediate strength absorbent solution is discharged from pump **72** through conduit **76.** A second portion of dilute absorbent solution is removed from absorber **16** via conduit **54** by pump **56.** This portion of dilute absorbent solution is discharged from pump **56** through control valve **84,** heat exchanger **58,** heat exchanger **60,** conduit **62,** to the first stage generator **18.** Heat exchangers **58** and **60** serve to preheat the dilute absorbent solution for improved efficiency.

In the first stage generator **18** the dilute absorbent solution is heated by heat exchanger **34** and caused to boil. The water vapor thus generated in the first stage generator is conducted from the first stage generator via conduit **29** to vapor conducting heat exchanger **38** of the second stage generator **20.** The semiconcentrated absorbent solution from first stage generator **18** is conducted via conduit **64** through heat exchanger **60** and conduit **66** to second stage generator **20.** Heat exchanger **34** is supplied with high pressure steam from a source such as a boiler via conduit **32** through steam control valve **80.** Steam condensate from heat exchanger **34** is conducted through a steam trap **36** to steam condensate heat exchanger **90** within the second stage generator **20.** As an alternative, not shown, the condensate leaving trap **36** may be heat exchanged with the solution passing from heat exchanger **60** in conduit **62** before passing to heat exchanger **90** for even greater efficiency. Both valves **80** and **84** are controlled by a controller **82** responsive to load conditions as sensed by the temperature of the chilled water leaving the evaporator at **83.** The first stage generator is enclosed by a shell or wall **35.**

Partially concentrated absorbent solution entering the second stage generator **20** from conduit **66** is heated by heat exchangers **38** and **90** and caused to boil. The water vapor thus generated in the second stage generator **20** passes through a liquid eliminator **42** into condenser **12** while the remaining concentrated absorbent solution is conducted from the second stage generator via conduit **68,** heat exchanger **58,** and conduit **70** to the inlet of pump **72** for admission to the absorber via conduit **76** and spray nozzles **78** as aforeherein described. The steam condensate passing in heat exchanger **90** is returned to the steam source via conduit **91.** The water vapor passing in heat exchanger **38** is caused to condense and the condensate is passed through condensate trap **40** to condenser **12** via conduit **41.** The second stage generator is enclosed by wall **43.**

Condenser **12** is enclosed by pan or wall **29.** A heat exchanger **28** is arranged to conduct cooling water from conduit **26** to cool condenser **12,** the cooling water being discharged from condenser **12** via conduit **30** from which it may be returned to the cooling water source such as a water cooling tower. The vapor passing through liquid eliminators **42** and the refrigerant condensate passing from conduit **41** are cooled by heat exchanger **28,** the vapors being thereby caused to condensed. The cooled and condensed refrigerant passes from condenser **12** through an opening **44** in pan **29** to flow directly into the evaporator **14.**

It will be understood that shell **10** includes a tube sheet **51** at each end thereof. Walls **35, 43, 29, 47** extend the full length of shell **10** and are sealingly engaged with the tube sheets **51.** The tubes of heat exchangers **34, 38, 90, 28, 46, 22,** extend into tube sheets **51** at opposite ends. The inlets and outlets to these heat exchangers while shown schematically in FIG. **1** are in actual practice made by appropriate headers connected to the tube sheets **51.**

Generator **20** is shown in more detail in FIGS. **2–12.** Pan or wall **43** is in the form of a channel which as aforementioned extends between tube sheets **51.** Fixedly disposed within the channel are a plurality of longitudinally spaced fixed tube supports **86.** Each fixed tube support is comprised of a vertical plate having a plurality of apertures disposed in alignment with similar aperatures in tube sheets **51** for receiving the bundle **87** of cupro-nickel tubes **88** of heat exchanger **38** and the bundle **89** of cupro-nickel or stainless steel tubes **91** of heat exchanger **90.** The fixed tube support aperatures are bored to a size of 0.003 to 0.010 inch larger than the outer diameters of the tubes in the unheated condition to accommodate thermaldiametrical expansion, bending and longitudinal movement of the tubes therein. However, these apertures are sufficiently small to prevent any substantial lateral movement of the tubes therein. The tubes are of course expanded or otherwise conventionally sealed within tube sheets **51.**

Within channel or wall **43** between each pair of fixed tube supports **86** and between each tube sheet **51** and its most adjacent fixed tube support **86** is a floating tube support **92** for supporting the tubes **88** of tube bundle **87** and the tubes **91** of tube bundle **89.** The floating tube supports are limited in longitudinal movement along the channel **43** by stops or guide **93** in the form of angle members welded to the base of channel member **43** as will be seen in FIG. **6.** The spacing of stops **93** on opposite sides of the floating tube support **92** is normally such as to permit floating tube support **92** to move longitudinally a greater distance than the thickness of floating tube support **92.** Floating tube supports **92** are comprised of metallic plates with through going holes to receive tubes **88** and **91.** The holes in floating tube supports **92** are in the order of 0.003 to 0.010 so that the tubes are constrained against any substantial lateral movement relative to the floating tube support **92** but may move laterally with the floating tube support **92.**

Floating tube supports **92** may be divided into two groups, a first set of alternate floating tube supports **94** and a second set of alternate floating tube supports **95.** Floating tube supports **94** are constructed and supported so they can move laterally only to one side of their position assumed when the tubes are in a straight condition as shown in FIG. **2,** that is when the heat exchangers **38** and **90** are at approximately room temperature. Floating tube supports **95** are constructed and supported so that they can move laterally only to the other side of their position assumed when the tubes are in the aforesaid straight condition. By constructing and supporting the floating tube supports in this manner the tubes will assume a wave-like configuration upon being heated to operating temperatures as will be seen more readily in FIG. **7.**

Each floating tube support **94** is comprised of a major plate member **94*a*** which traverses or encompasses the tubes **88** of tube bundle **87** and a minor plate member **94*b*** which traverses or encompasses the tubes **91** of tube bundle **89.** Each plate member **94*a*** is separate and free to move relative to its associated plate member **94*b***. Adjacent or associated plate members **94*a*** and **94*b*** are maintained in coplanar relationship by an alignment means **96** hereinafter described. In like manner each of floating tube supports **95** is comprised of a major plate member **95*a*** which traverses or encompasses the tubes **88** of tube bundle **87** and a minor plate member **95*b*** which traverses or encompasses the tubes **91** of tube bundle **89.** Each of plate members **95*b*** is separate and free to move relative to its associated plate member **95*a***. Also adjacent or associated plate members **95*a*** and **95*b*** are maintained in coplanar relationship by alignment means **96.**

Each of alignment means **96** is comprised of a rod or protrusion **97** fixedly secured to a minor plate member and a socket member **98** fixedly secured to the major plate member for slidably receiving rod **97.** Such alignment means **96** is disposed both adjacent the top and bottom of each of the floating tube supports.

It will be noted that major plate members **95*a*** are constrained against lateral movement to one side of their position shown in FIG. **2** by reason of their abutment or contact at **99** with one wall of channel member **43.** Minor plate members **95*b*** are similarly constrained against lateral movement to one side of their position shown in FIG. **2** by reason of their abutment or contact at **100** with major plate members **95*a***. Minor plate members **94*b*** are constrained against lateral movement to the other side of their position shown in FIG. **2** by reason of their abutment or contact at **101** with the other wall of channel member **43.** Each of major plate members **94*a*** is provided with a protrusion **102** fixedly secured thereto which abuts said other wall of channel member **43** at **103** for constraining the major plate member **94*a*** against lateral movement to said other side of its position shown in FIG. **2.**

It will thus be seen that when tubes **91** of tube bundle **89** and tubes **88** of tube bundle **87** are heated to the same temperature and thereby caused to elongate, they will assume the wave-like pattern illustrated in FIG. **7.** However, during start up conditions or during idle periods when steam control valve **80** may leak thereby permitting the tubes **91** of tube bundle **89** of heat exchanger **90** to become heated while the tubes **88** of tube bundle **87** of heat exchanger **38** remain relatively cool or at ambient temperature, the tubes will assume the position shown in FIG. **10.** Thus it will be noted that the tubes of tube bundle **89** are free to move laterally to a limited extent without interference from the tube bundle **87.** However, it does not follow that the tubes **88** of tube bundle **87** can move laterally without interference with the tubes **91** of tube bundle **89** by reason of the abuting relation of major plate members **95*a*** and minor plate members **95*b*** at **100.** By reason of this same relationship it will be seen that tube bundle **87** in moving from its ambient temperature position shown in FIG. **2** to its heated position shown in FIG. **7** actually occupies a portion of the space previously occupied by tube bundle **89.** By reason of this construction a more compact double tube bundle construction is achieved. It will be further noted that alignment means **96** are necessary to establish the abutment at **100** and also serve to prevent the gouging of tubes of one tube bundle by the floating tube support plate members of the other tube bundle.

Therefore, what is claimed is:

1. In a two stage absorption refrigeration machine wherein the second stage generator is heated by water vapor generated in the first stage generator and water condensate formed in the first stage generator from heating steam supplied through a steam control valve, a second stage generator comprising: a shell defining an enclosure; first conduit means for passing an absorption solution from said first stage generator into said enclosure; a first elongated tube bundle extending through said enclosure; a second elongated tube bundle extending through said enclosure; second conduit means for passing water vapor that is generated in said first stage generator through the tubes of said first tube bundle; third conduit means for passing steam condensate that is formed in said first stage generator through the tubes of said second tube bundle; each of said tube bundles being fixedly supported at their ends by said shell; and means intermediate the ends of said second tube bundle to accommodate longitudinal expansion of the tubes of said second tube bundle relative to the tubes of said first tube bundle during idle and start up conditions of said refrigeration machine.

2. In a two stage absorption refrigeraton machine wherein the second stage generator is heated by water vapor generated in the first stage generator and water condensate formed in the first stage generator from heating steam supplied through a steam control valve, a second stage generator comprising: a shell defining an enclosure; first condiut means for passing an absorption solution from said first stage generator into said enclosure; a first elongated tube bundle of first tubes extending through said enclosure; a second elongated tube bundle of second tubes extending through said enclosure; second conduit means for passing water vapor that is generated in said first stage generator through said first tubes of said first tube bundle; third conduit means for passing steam condensate that is formed in said first stage generator through said second tubes of said second tube bundle; each of said tube bundles being supported by longitudinally spaced alternately fixed and floating tube supports; at least some of said floating tube supports of said second tube bundle being relatively movable with respect to the floating tube supports of said first tube bundle to permit longitudinal expansion of said second tubes of said second tube bundle relative to said first tubes of said first tube bundle during idle and start up conditions of said refrigeration machine.

3. Apparatus as defined by claim **2** wherein the floating tube supports of said second tube bundle are disposed substantially longitudinally coextensive along said first and second tubes with the floating tube supports of said first tube bundle.

4. Apparatus as defined by claim **3** including guide means connected to the upper portions of longitudinally coextensive floating tube supports to maintain the upper portions of said floating tube supports in said longitudinally coextensive relationship.

5. Apparatus as defined by claim **3** wherein said guide means includes protruding member carried by one of said floating tube supports of one of said tube bundles and a socket member carried by one of said floating tube supports of the other of said tube bundles, said protruding member being slidably disposed in said socket member for movement substantially normal to the longitudinal axes of said first and second tubes for maintaining the associated floating tube supports of each tube bundle in substantially longitudinally coextensive relationship.

6. Apparatus of claim 5 wherein said first tubes and said second tubes have a substantially straight natural configuration and said fixed and floating tube supports are disposed intermediate the ends of each of said tube bundles to constrain each of said tube bundles into a wave-like configuration.

7. Apparatus of claim 6 including first limit means operatively associated with each of said floating tube supports of said first tube bundle for substantially limiting, at the respective floating tube support substantial relative lateral movement between said first tubes while permitting said first tubes to float as a group; second limit means operatively associated with each of said floating tube supports of said second tube bundle for substantially limiting, at the respective floating tube support substantial relative lateral movement between said second tubes while permitting said second tubes to float as a group; and third limit means operatively associated with each of said fixed tube supports for substantially limiting at said fixed tube supports, relative lateral movement between said first tubes, between said second tubes, and between said first and second tubes, while permitting said first and second tubes to pivot relative to the respective fixed tube support.

8. Apparatus as defined by claim 7 including abutment means associated with each of said floating tube supports of each of said first and second tube bundles to permit each floating tube support to move laterally substantially only to one side of its position assumed when the tubes supported thereby are straight; said abutment means permitting longitudinally spaced adjacent floating tube supports to move substantially only to opposite sides and longitudinally spaced alternate floating tube supports to move substantially only to common sides.

9. Apparatus as defined in claim 8 wherein said abutment means are located to permit said second tubes of said second tube bundle to move from said natural straight configuration to said wave-like configuration without said floating tube supports of said second tube bundle interferring with the floating tube supports of said first tube bundle.

10. Apparatus as defined by claim 9 wherein said abutment means are located to permit longitudinally spaced alternate floating tube supports of said first tube bundle, when in the wave-like configuration, to occupy the space occupied by said floating tube supports of said second tube bundle when the tubes thereof are in their substantially straight natural configuration.

11. Apparatus as defined by claim 10 wherein longitudinally coextensive fixed tube supports of each of said first and second tube bundles are integral.

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