

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

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[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

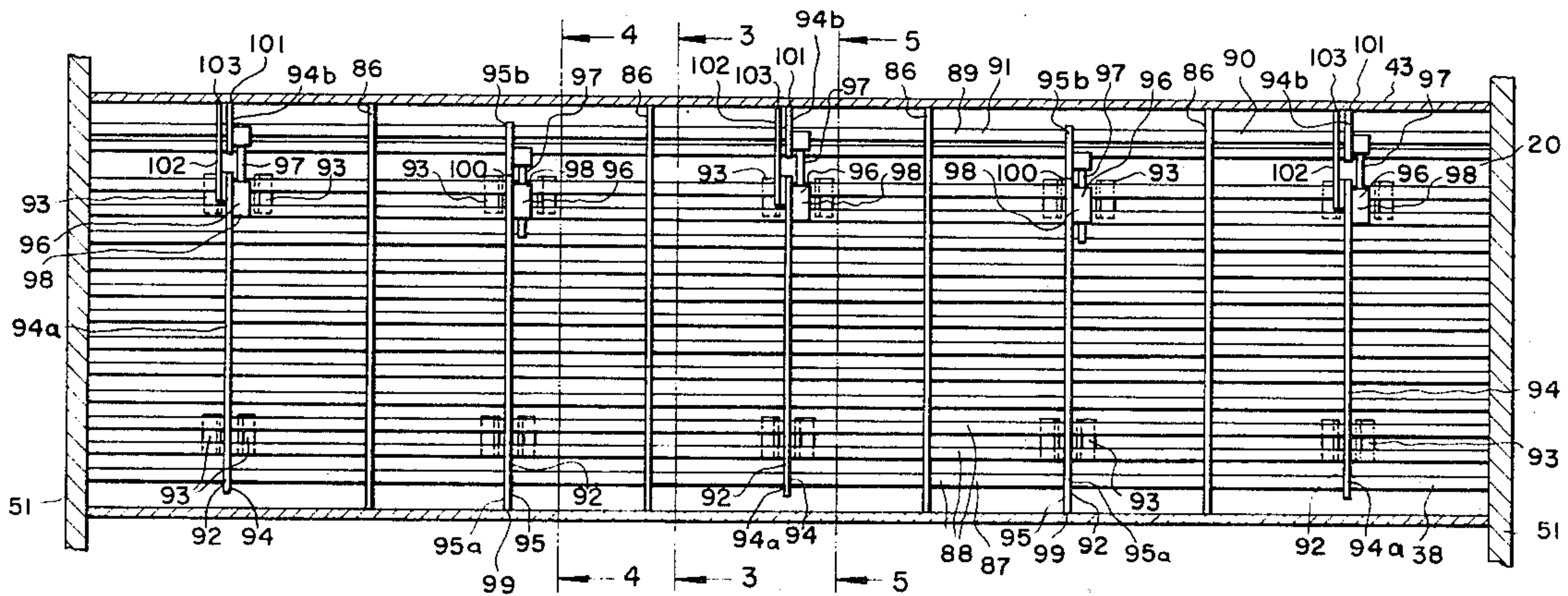
3,012,761	12/1961	Gardner et al.....	165/162 X
3,212,570	10/1965	Holman	165/162
3,550,394	12/1970	Peckham	62/497 X
3,659,431	5/1972	Iwasawa.....	62/476

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[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



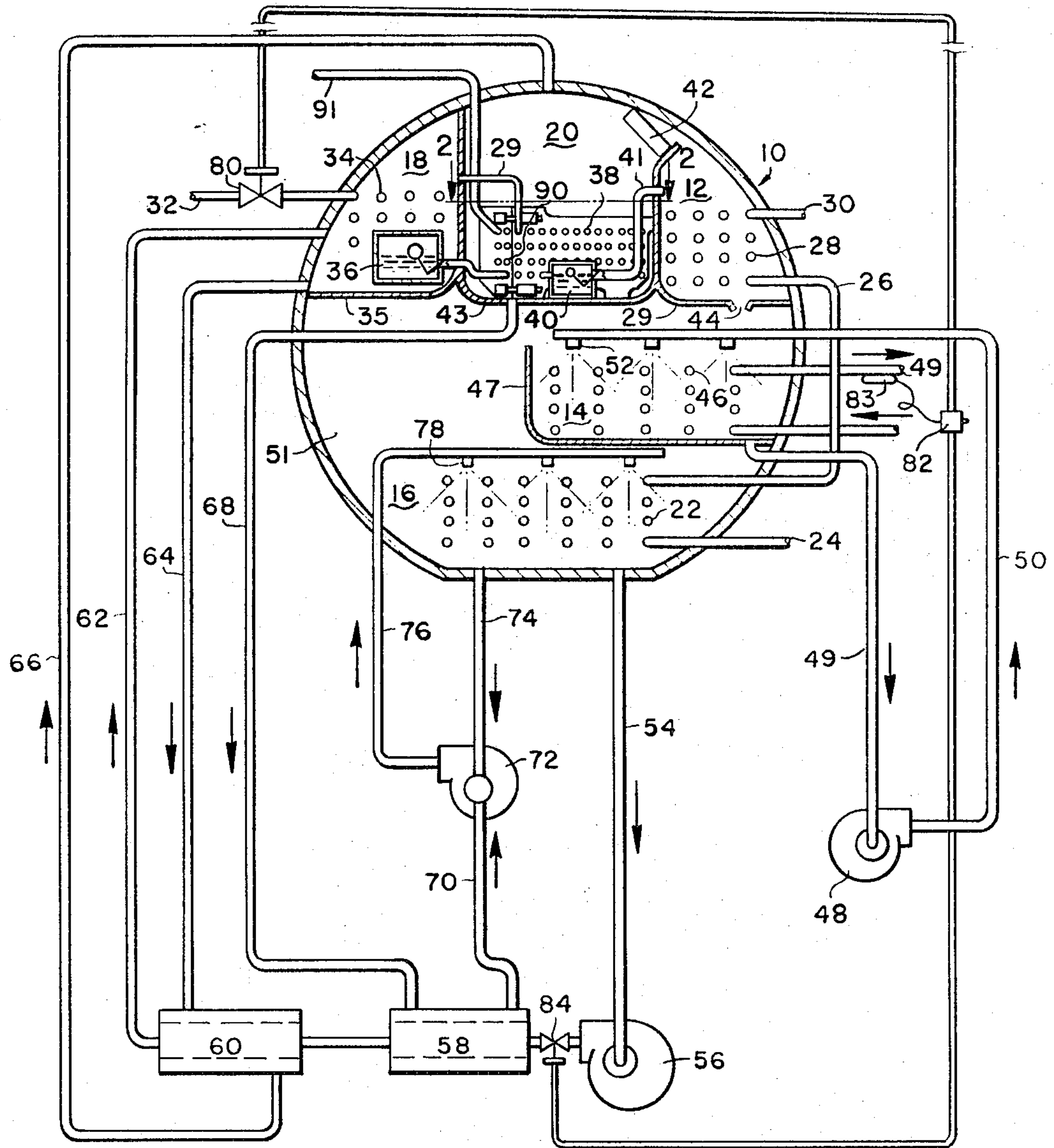


FIG. 1

FIG. 7

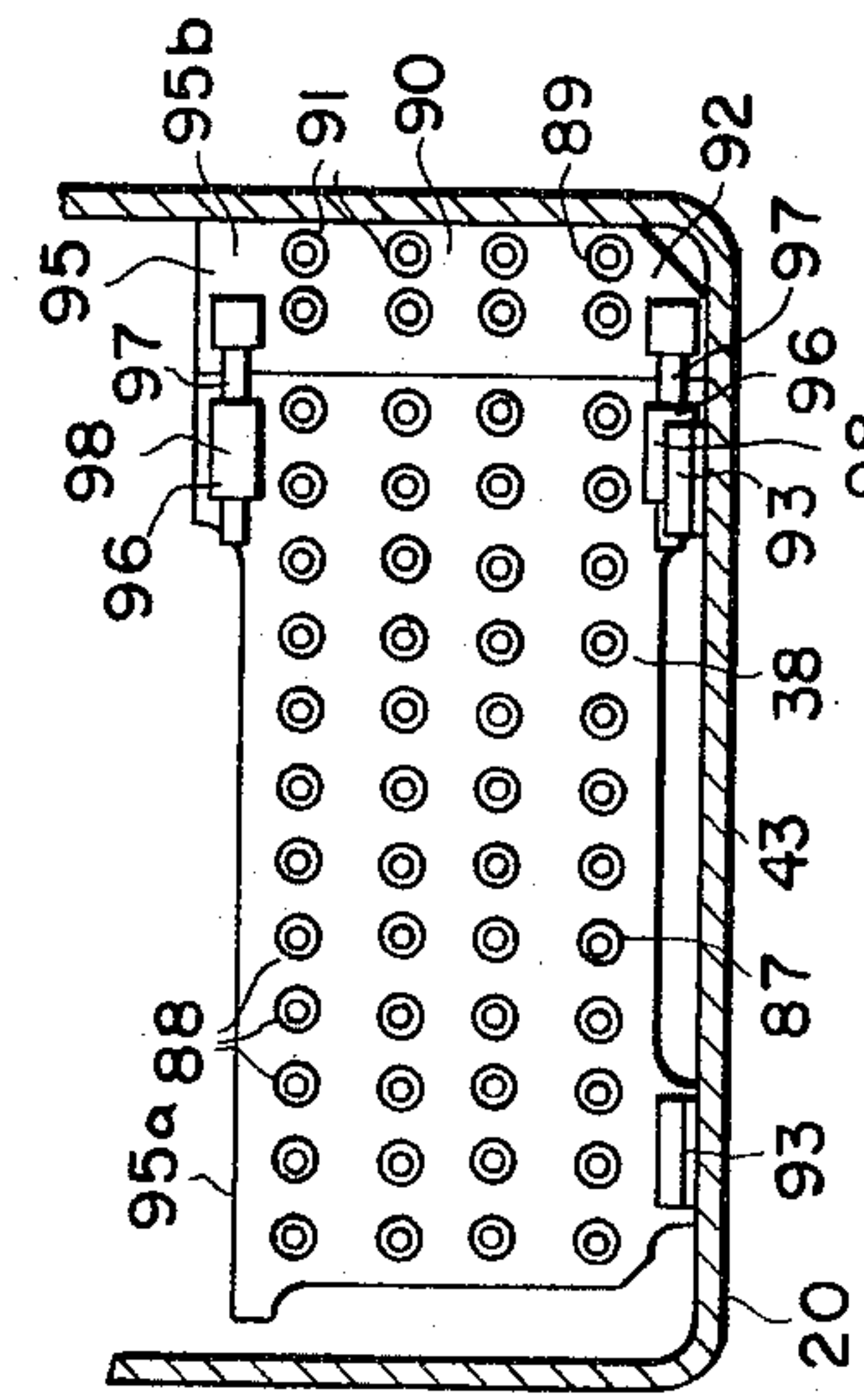
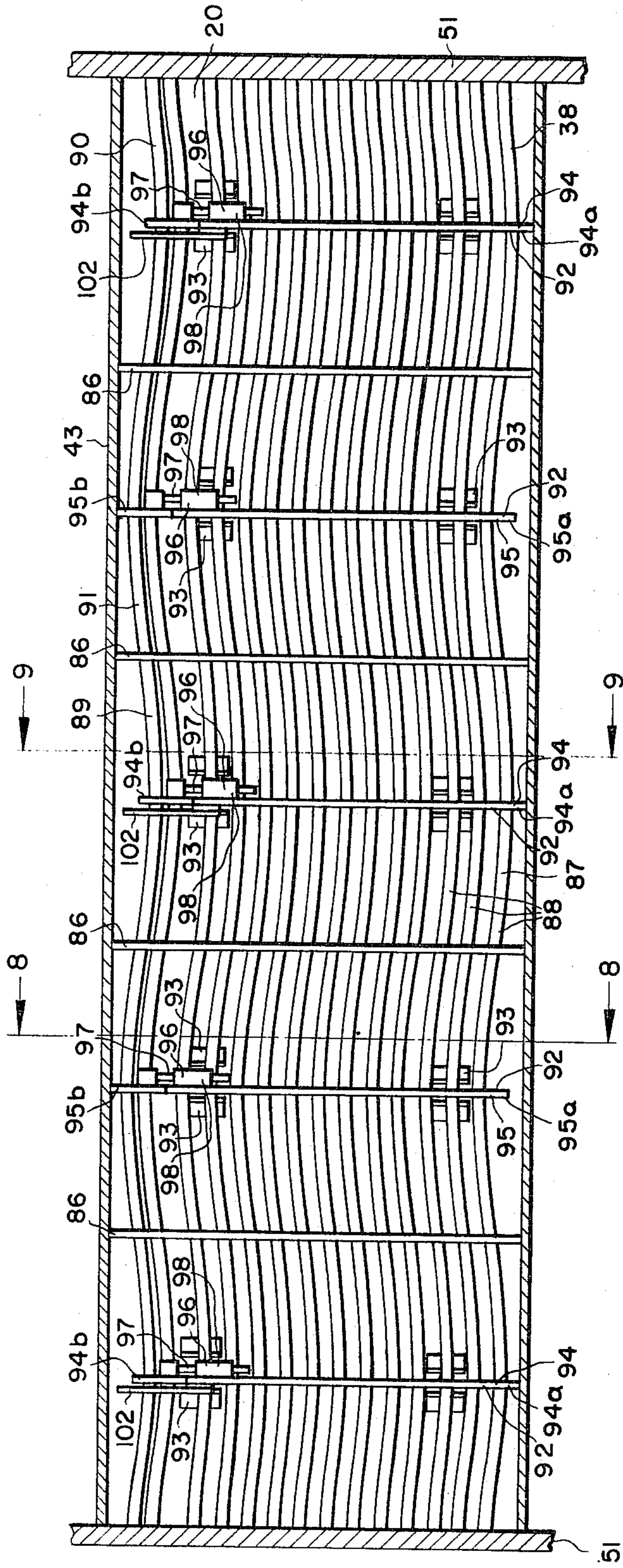


FIG. 8

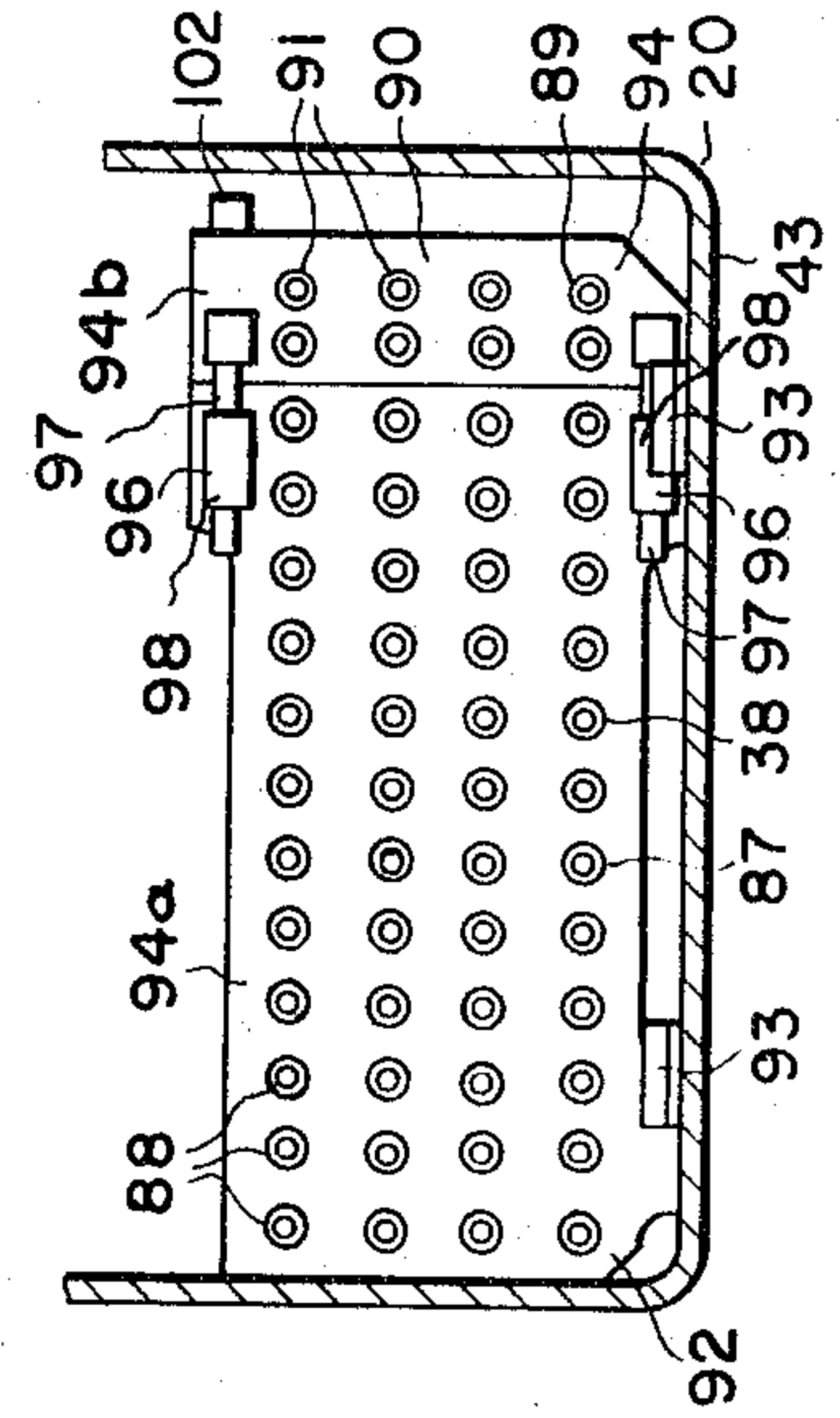


FIG. 9

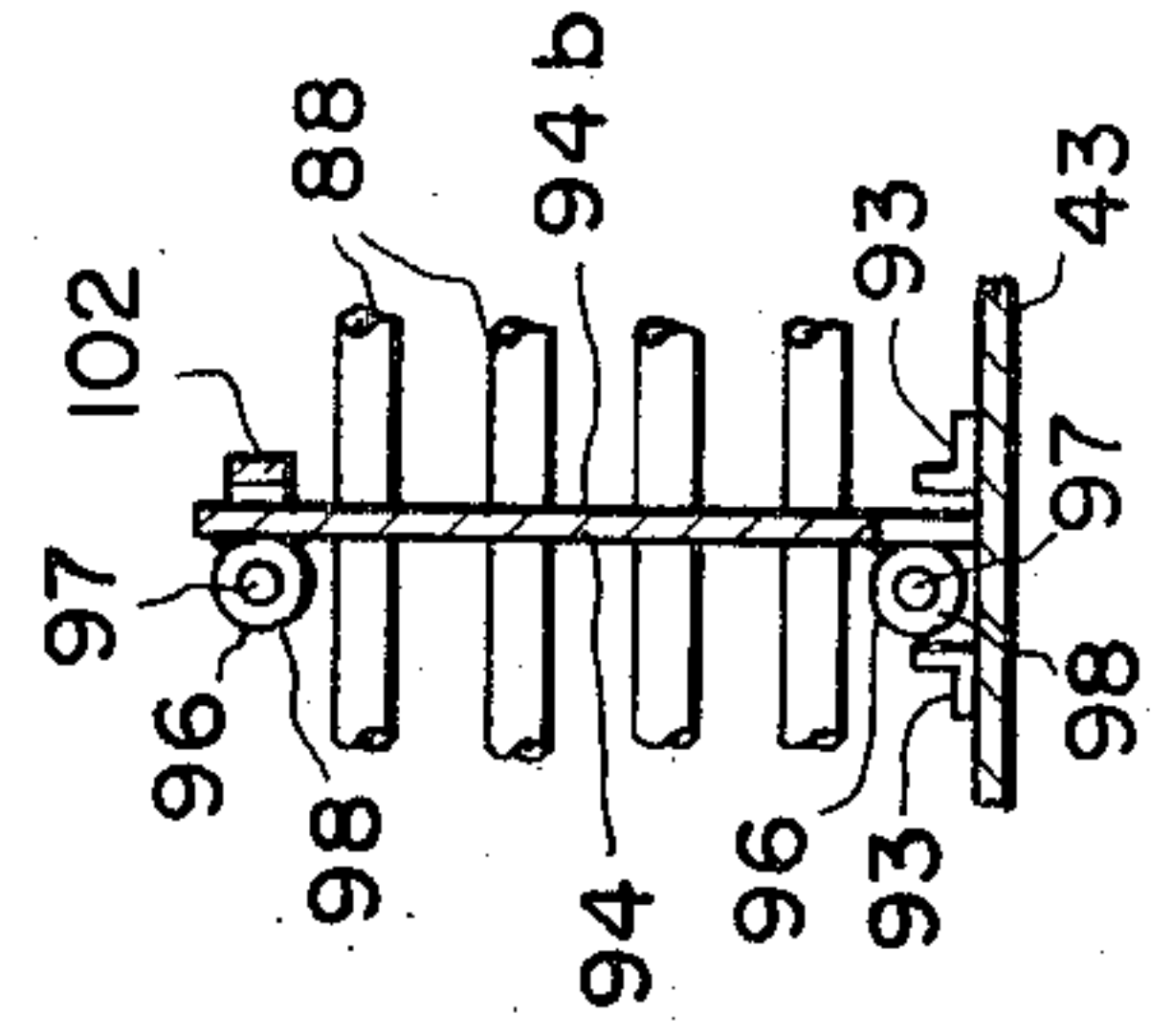


FIG. 6

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 herein 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 condense. 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 en-

gaged 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 apertures 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 apertures 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 thermal diametrical 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 94a which traverses or encompasses the tubes 88 of tube bundle 87 and a minor plate member 94b which traverses or encompasses the tubes 91 of tube bundle 89. Each plate member 94a is separate and

free to move relative to its associated plate member 94b. Adjacent or associated plate members 94a and 94b 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 95a which traverses or encompasses the tubes 88 of tube bundle 87 and a minor plate member 95b which traverses or encompasses the tubes 91 of tube bundle 89. Each of plate members 95b is separate and free to move relative to its associated plate member 95a. Also adjacent or associated plate members 95a and 95b 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 95a 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 95b 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 95a. Minor plate members 94b 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 94a 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 94a 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 abutting relation of major plate members 95a and minor plate members 95b 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 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 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

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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

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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 interfering 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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