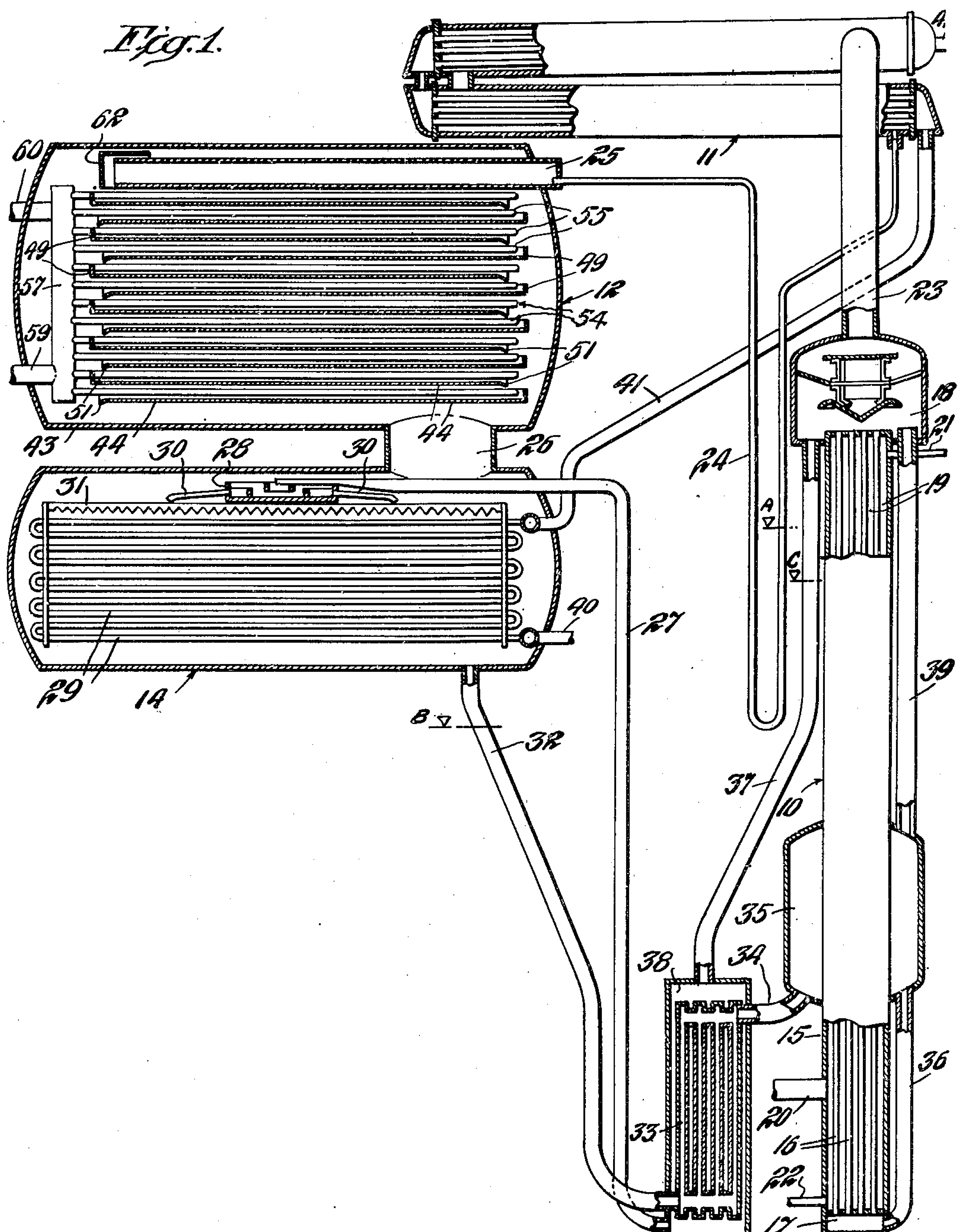
Oct. 25, 1949. J. G. REID, JR 2,485,844

EVAPARATOR HAVING AN EXTENDED VAPORIZING SURFACE AREA

Filed Aug. 31, 1946 3 Sheets-Sheet 1

Fig. 1.



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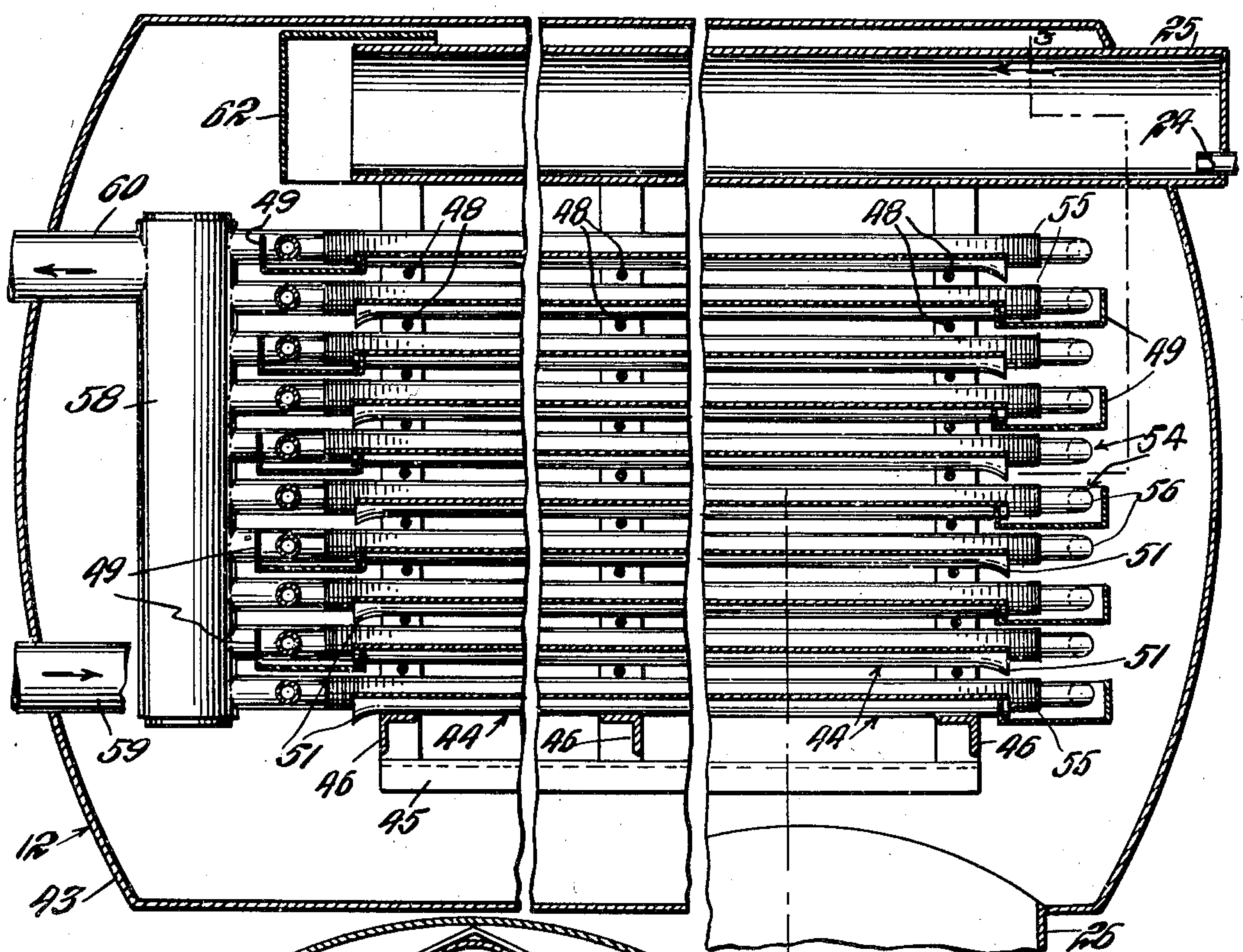

Fig. 2.

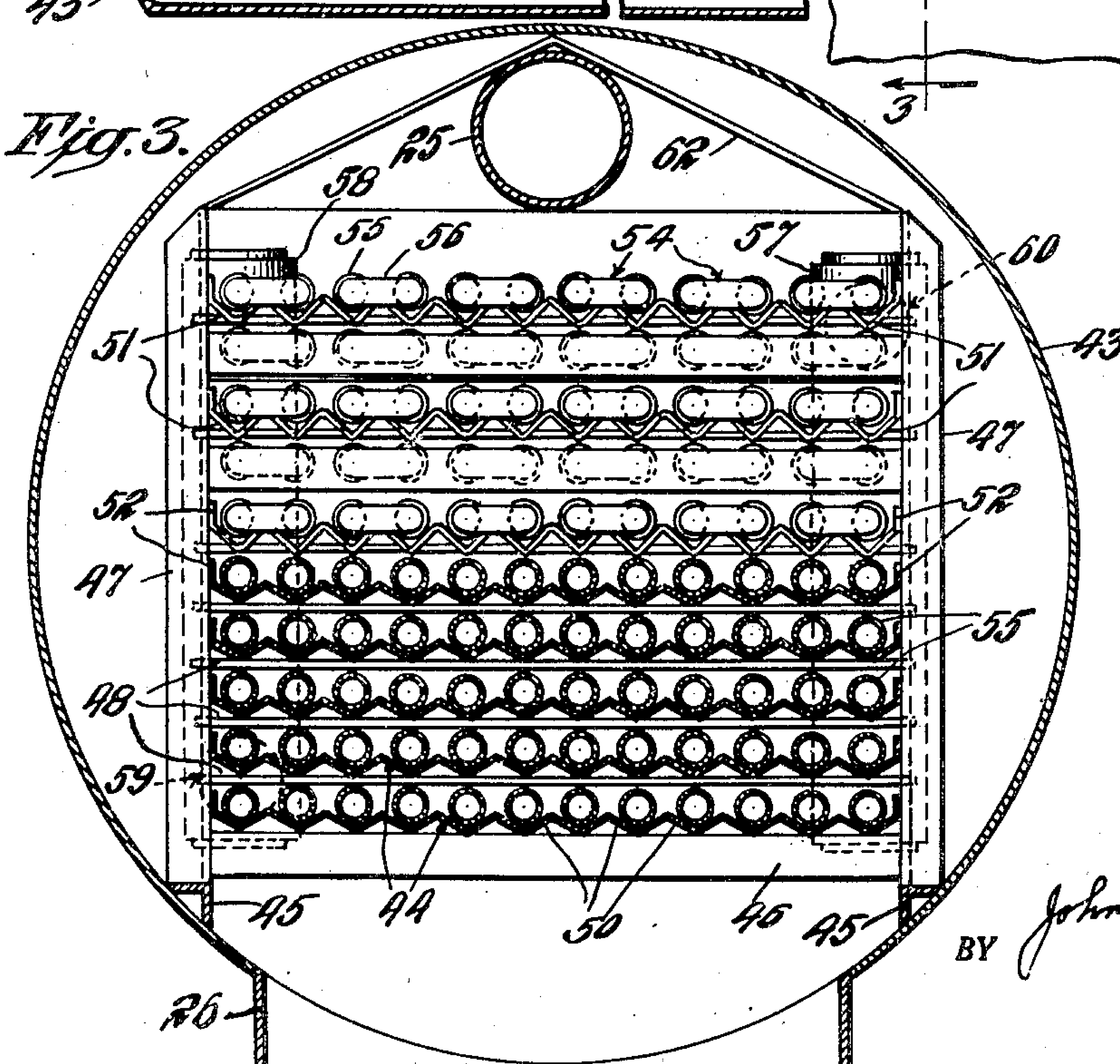

Fig. 3.

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Fig. 4.

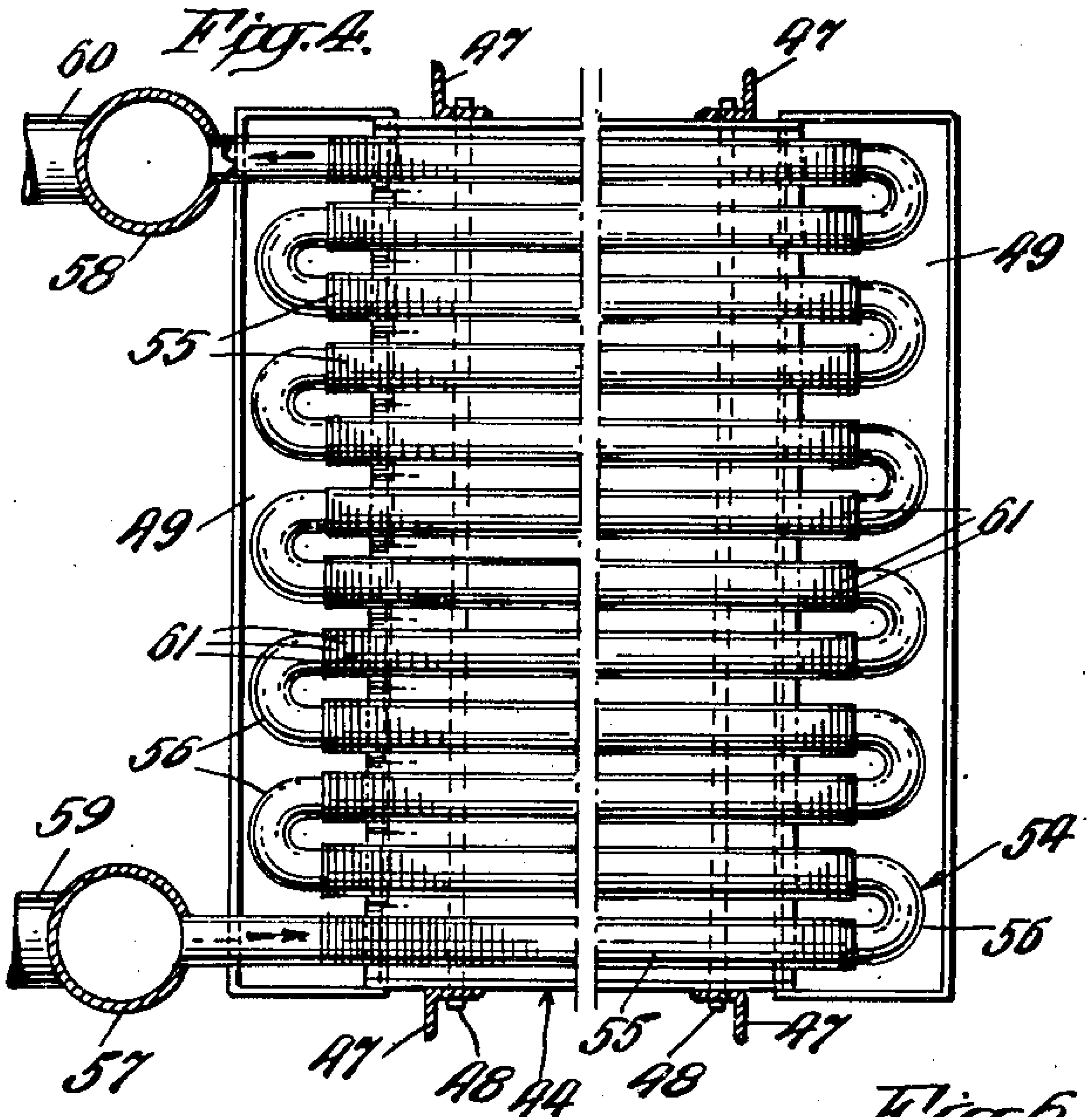


Fig. 5.

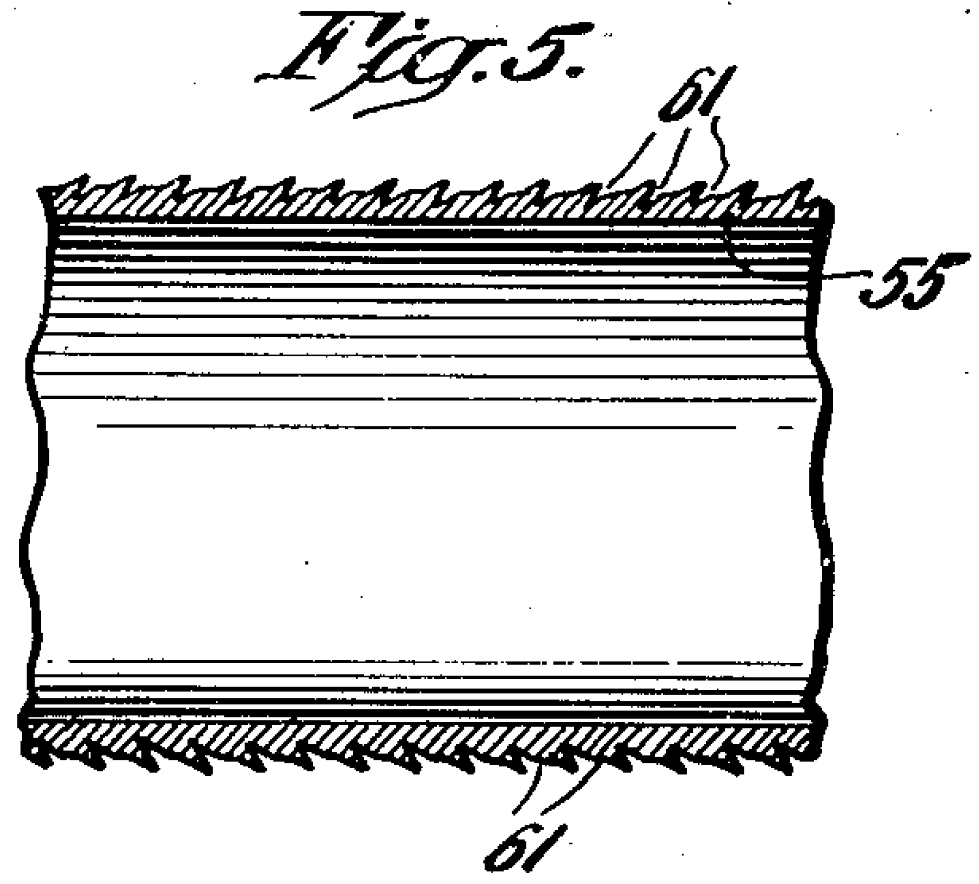
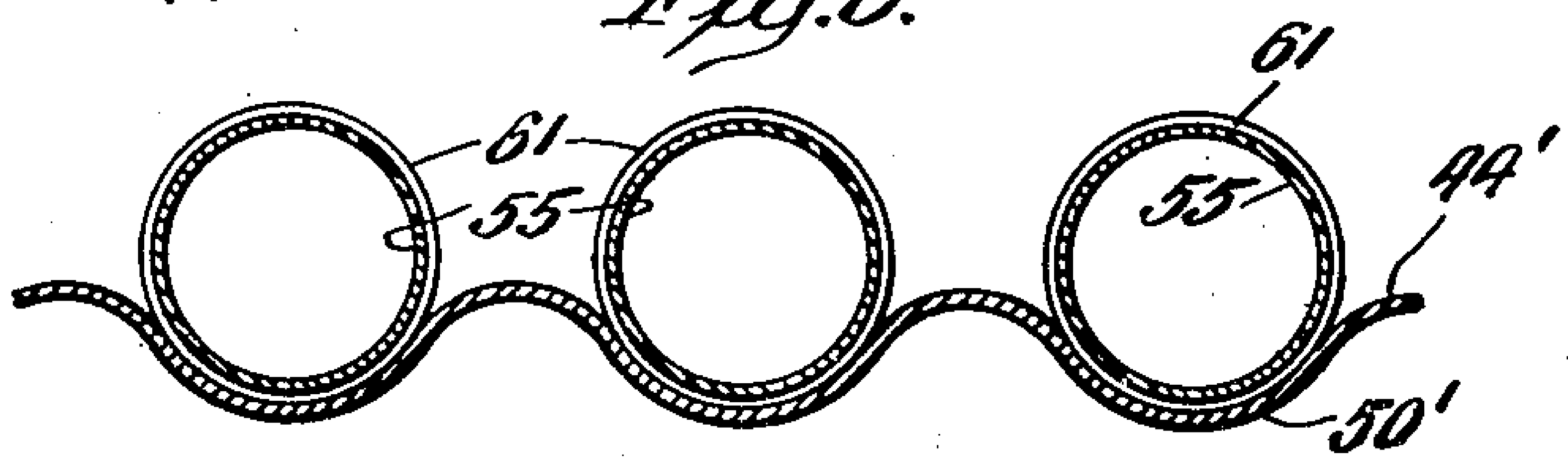


Fig. 6.



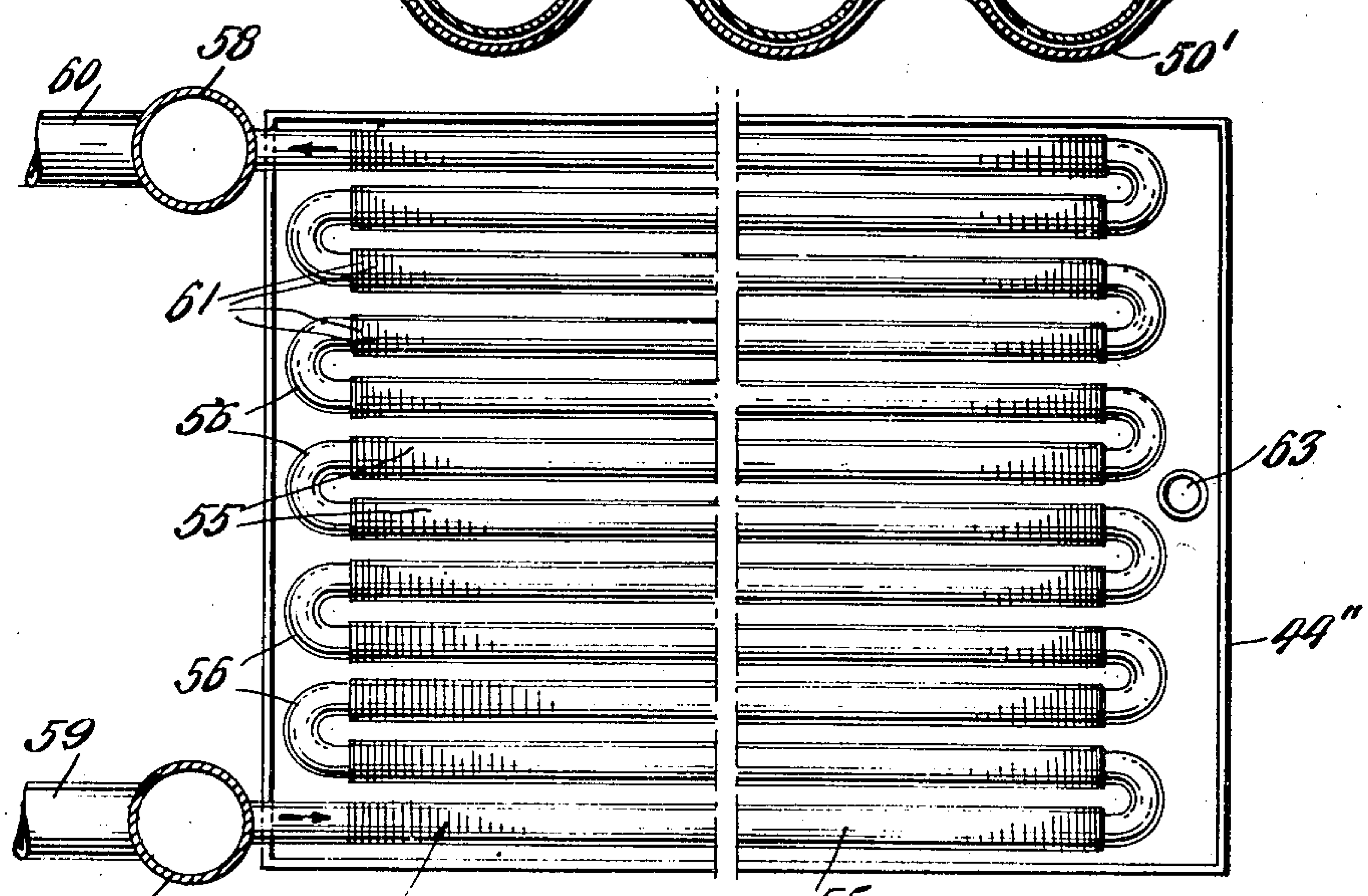


Fig. 7.

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EVAPORATOR HAVING AN EXTENDED VAPORIZING SURFACE AREA

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8 Claims. (Cl. 62—126)

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This invention relates to refrigeration and particularly to evaporator structures for low pressure or vacuum type refrigerating systems.

When water or similar liquid is used as the refrigerant in a vacuum system the volume of vapor produced by the vaporization of the liquid in the evaporator is enormous as compared to the volume of liquid refrigerant supplied to the evaporator. If the refrigerant is appreciably confined in the evaporator, as in coils, this great volume of vapor causes a high velocity of vapor flow through the evaporator, and this results in an unequal distribution of the liquid refrigerant in the evaporator and the blowing of liquid refrigerant through the evaporator without its being vaporized and picking up heat as intended.

This invention turns the prior art inside out—the refrigerant liquid is distributed on the outside of a tube so the tube size is no longer a critical factor of the vapor velocity, and the liquid quantity is not affected because it is lifted and distributed over the outside of the tube just as it was on the inside in the prior art—by capillarity. Outside of the tube any area necessary can be provided for vapor flow so the velocity can be lowered without affecting any desirable factor but yet eliminating the violent liquid disturbance.

One way of utilizing the invention is by constructing the evaporator of an absorption refrigerating system of the vacuum type of a plurality of horizontal rows of conduits arranged in vertical spaced relation and suitably supported in an evaporator shell or housing. The conduits are connected at their ends by return bends forming horizontal coils. The coils are connected at their inlet and outlet ends to a pair of vertical headers. The arrangement is such that a liquid to be cooled, for example, water as a secondary cooling medium, flows from a cooling element which is located in the path of flow of air to be cooled into one of the headers, through the interior of the conduits, into the other header and back to the cooling element. Directly beneath each horizontal row of conduits is located a shallow tray. Liquid refrigerant flows from the condenser of the refrigerating system through a flash chamber into the uppermost of the shallow trays, across the tray to the opposite end thereof, into the next lower tray, to the opposite end thereof, and so on to the other trays in series.

The conduits of the horizontal coils are grooved or rifled on their outer surface to provide capillary grooves which pick up the liquid refrigerant passing across the shallow trays thereby forming a thin film of liquid over the entire outer surface

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of the conduits. By this arrangement the film of liquid refrigerant evaporates on the outer surface of the conduits without disturbing the shallow pools of refrigerant contained in the trays and without disturbing the film of refrigerant that is formed upon the outer surface of the other conduits. The secondary heat transfer medium flowing through the conduits gives up its heat to the refrigerant on the outer surface thereof, causing the refrigerant to evaporate. The evaporator shell provides ample space for the vaporized refrigerant to pass to the absorber of the refrigerating system without an appreciable increase in velocity.

This invention will be more fully understood by reference to the following description taken in connection with the accompanying drawings wherein:

Fig. 1 is a view diagrammatically illustrating a refrigerating system incorporating my invention;

Fig. 2 is a longitudinal vertical sectional view of my improved evaporator;

Fig. 3 is a transverse vertical sectional view taken substantially on line 3—3 of Fig. 2;

Fig. 4 is a top plan view, partly in section, of the evaporator illustrated in Figs. 2 and 3 with certain parts omitted for clarity of illustration;

Fig. 5 is an enlarged sectional view of part of an evaporator conduit in accordance with my invention;

Fig. 6 is a partial transverse sectional view illustrating a modification of my invention; and

Fig. 7 is a top plan view similar to Fig. 4 illustrating another embodiment of my invention.

Referring to Fig. 1, the present invention is embodied in a two pressure absorption refrigerating system like that disclosed in United States patent to A. R. Thomas and P. P. Anderson, Jr., No. 2,282,503, granted May 12, 1942. A system of this type operates below atmospheric pressures and includes a generator or vapor expeller 10, a condenser 11, an evaporator 12, to be referred to in detail hereinafter, and an absorber 14 which are interconnected in such a manner that the pressure differential in the system is maintained by liquid columns.

The disclosure in the aforementioned Thomas and Anderson patent may be considered as being incorporated in this application, and, if desired, reference may be had thereto for a detailed description of the refrigerating system. In Fig. 1 the generator 10 includes an outer shell 15 within which are disposed a plurality of vertical riser tubes 16 having the lower ends thereof communicating with a space 17 and the upper ends thereof extending into and above the bottom of a separating vessel 18. A space 19 within the shell 15 forms a steam chamber about the tubes 16 to which steam is supplied through a conduit 20. The space 19 provides for full length heating of tubes 16, a vent conduit 21 being provided at the upper end of shell 15. A conduit 22 is connected to the lower part of shell 15 for draining condensate from the space 19.

The system operates at a partial vacuum and contains a water solution of refrigerant in absorbent liquid such as, for example, a water solution of lithium chloride or lithium bromide or a mixture of the two. With steam being supplied through conduit 20 to space 19 at atmospheric pressures, heat is applied to tubes 16 whereby water vapor is expelled from solution. The residue absorption liquid is raised by gas or vapor-lift action with the expelled water vapor forming a small core within an upwardly rising annulus of the liquid. The expelled water vapor rises more rapidly than the liquid with the liquid flowing along the inside walls of the tubes 16.

The water vapor flows upwardly through the tubes or risers 16 into vessel 18 which serves as a vapor separator. Due to baffling in vessel 18, water vapor is separated from raised absorption solution and flows through conduit 23 into condenser 11. The condensate formed in the condenser flows through a U-tube 24 into a flash tube 25 and from there into the top distributing tray of my improved evaporator 12, to be referred to in more detail hereinafter. The water supplied to the evaporator evaporates therein to produce a refrigerating or cooling effect with consequent absorption of heat. The vapor formed in the evaporator passes to the absorber 14 through a relatively large conduit 26 connected between the lower part of the evaporator and the upper part of the absorber.

In the absorber refrigerant vapor is absorbed into concentrated absorption liquid which enters through a conduit 27. The entering absorption liquid flows into a vessel 28 in which the liquid is distributed laterally or crosswise of a plurality of vertically disposed pipe banks 29 which are arranged alongside of each other. The liquid flows from vessel 28 through conduits 30 into a plurality of liquid holders and distributors 31 which extend lengthwise of and above the upper horizontal branches of the pipe banks 29. Absorption liquid is distributed over the upper horizontal branches of the pipe banks and the liquid drops from each horizontal pipe section onto the next lower pipe section, whereby all of the pipe sections are wetted with a film of liquid.

The water vapor formed in evaporator 12 and passed through conduit 26 into the absorber 14 is absorbed by the absorption liquid therein and, due to such absorption of water vapor, the absorption liquid is diluted. The diluted absorption liquid flows through a conduit 32, through the inner passage 33 of a liquid heat exchanger, through conduit 34 into a stabilizing vessel 35 and from there through a conduit 36 into space 17 at the lower part of generator 10. Water vapor is expelled out of solution in generator 10 by heating, and the solution is raised by gas or vapor-lift action in riser tubes 16, as above explained.

The absorption liquid in vessel 18 is concentrated since water vapor has been expelled therefrom in generator 10. The concentrated absorption liquid flows through a conduit 37, a second passage 38 of the liquid heat exchanger, and conduit 27 into the upper part of absorber 14. This circulation of absorption liquid results from the rising of liquid by vapor-lift action in vertical riser tubes 16, whereby the liquid can flow to the absorber and return from the latter to the generator by force of gravity. The upper part of stabilizing vessel 35 is connected by a conduit 39 to the separating vessel 18, so that pressure in the vessel is equalized with the pressure in the generator. This conduit 39 also acts as a vent between the vessel 35 and the vessel 18.

The heat liberated by the absorption of water vapor in absorber 14 is transferred to a cooling medium, such as water, for example, which flows upward through the vertically disposed pipe banks 29. The cooling medium enters the lower ends of pipe banks 29 through a conduit 40 and leaves the upper ends of the pipe banks through a conduit 41. Conduit 41 is connected to condenser 11 whereby the same cooling medium may be utilized to cool both the condenser and the absorber, and from the condenser the cooling medium flows through a conduit 42 to waste or to a cooling tower, not shown.

The system operates at low pressures with the generator 10 and condenser 11 operating at one pressure and the evaporator 12 and absorber 14 operating at a lower pressure, the pressure differential between being maintained by liquid columns. Thus, the liquid column formed in U-tube 24 maintains the pressure differential between condenser 11 and evaporator 12, the liquid column in conduit 32 maintains the pressure differential between the outlet of the absorber and the inlet of the generator, and the liquid column formed in conduit 27 maintains the pressure differential between the inlet of the absorber and the upper part or outlet of the generator. In operation, the liquid columns may form, for example, in the down leg of U-tube 24, and in conduits 32 and 37 to levels A, B and C, respectively.

Referring now to Figs. 2, 3 and 4 of the drawings, my improved evaporator is shown as comprising an elongate cylindrical shell 43 within which is supported a plurality of shallow horizontal trays disposed in vertical spaced relation and designated generally by numeral 44. The supports for trays 44 include a pair of angle members 45 disposed longitudinally of the shell and secured thereto as by welding, a plurality of transverse angle members 46 welded to angle members 45, a plurality of vertical angle members 47 secured as by welding to angle members 44 and 45 and a plurality of horizontal rods 48 upon which the trays rest and which pass through openings in angle members 47 and are secured thereto as by welding. As shown, the trays 44 each includes a transversely disposed horizontal distributing trough 49 arranged on alternate ends of successive trays. The tray bottom is provided with a plurality of V-shaped corrugations 50 opening at one end into the trough 49 and provided with drip extensions 51 on the opposite ends thereof. Upstanding sides 52 are provided along the longitudinal sides of the trays.

A plurality of horizontally disposed vertically spaced pipe coils 54 are arranged within the evaporator shell. These coils are formed of longitudinal conduits 55 connected at their ends by return bends 56. The longitudinal conduits lie within and are supported by the V-shaped corrugations of the trays 44. The inlet and outlet ends of coils 54 are connected to vertical headers 57 and 58, respectively. Headers 57 and 58 are connected by conduits 59 and 60, respectively, to a secondary cooling system including a cooling element, not shown, but which is located in the path of flow of air to be cooled. As shown particularly in Figs. 4 and 5, the longitudinal conduits 55 of the coils 54 are each provided with a helical capillary groove 61 on the exterior surface thereof. This groove is formed by cutting and swaging metal outward from the exterior surface of the tube. By this manner of forming the capillary groove the exterior surface area of the conduit is greatly increased without removing any metal from the conduit and without appreciably weakening the walls of the conduit.

As shown in Figs. 1 and 2, the flash tube 25, previously referred to, is located in the upper portion of the evaporator shell. This tube is closed at one end, except where U-tube 24 enters, and the opposite or outlet end is open. The flash tube 25 serves as a chamber in which may occur vapor flashing of liquid flowing from the condenser through U-tube 24 to the evaporator. The outlet end of the flash tube opens directly above and discharges liquid refrigerant into the distributing trough 49 of the uppermost tray 44. To prevent liquid refrigerant from being blown beyond the trough 49 a deflecting hood 62 is located in front of and around the sides and top of the outlet end of the flash tube.

In the operation of my improved evaporator, liquid refrigerant flows from the condenser through U-tube 24 into the flash tube 25 and, after having been flashed to the temperature corresponding to the pressure in the evaporator, flows from the flash tube into the distributing trough 49 of the uppermost of the trays 44, the deflecting hood 62 preventing liquid refrigerant from being blown beyond the end of the trough due to flashing. The liquid refrigerant spreads out in the distributing trough and flows out through the V-troughs under each of the longitudinal conduits 56 of the uppermost row of such conduits. The capillary grooves on the outer surface of these conduits causes liquid refrigerant to be lifted upwardly from the V-troughs onto the outer surface of the conduits to the top thereof wetting the entire outer surface thereof. Excess refrigerant runs from the opposite end of the V-troughs into the distributing trough of the next lower tray and so on down across the different trays in series flow. A secondary cooling medium, such as water, flows from the cooling element, not shown, through conduit 59 into vertical header 57, into the inlet ends of the different coils 54, through the coils into the outlet header 58, and from there through the conduit 60 back to the cooling element. In passing through the coils 54 the secondary heat transfer medium gives up heat to the film of liquid refrigerant on the outer surface of the conduits 55 whereby the liquid refrigerant is vaporized producing the desired cooling effect.

The liquid refrigerant is distributed in such manner throughout the distributing troughs 49, V-shaped troughs 50, and over the outer surface of the conduits 55 that at no time is there any more than a very shallow pool of liquid or a thin film of liquid on any of these elements. By this arrangement the storage of liquid refrigerant in the evaporator is maintained at a minimum, thus avoiding changes in the concentration of the saline solution in the other component parts of the refrigerating system, and, eliminating superheating and blowing out of liquid refrigerant in the evaporator proper. Furthermore, with the relatively great surface area upon which the liquid refrigerant evaporates and the substantially unconfined manner in which the refrigerant evaporates on this surface, the velocity of the refrigerant vapor is maintained at a minimum in the evaporator. The vapor formed by the evaporation of liquid refrigerant in the evaporator passes through the conduit 26 in the lower part of the evaporator shell and into the absorber 14, as explained above.

In the modification of my invention illustrated in Fig. 6, the tray 44′ is substantially the same as the trays 44 of Figs. 1 to 4, inclusive, except that in the modified form the corrugations 50′ are arcuate instead of V-shaped. The tray in this modified form functions substantially the same as those in Figs. 1 to 4, inclusive.

In the modification of my invention illustrated in Fig. 7, the tray 44″ is simply a flat bottom tray with upstanding sides and ends. This tray is provided with an overflow tube 63 which projects upwardly a short distance from the bottom of the tray to maintain a very shallow pool of liquid refrigerant in the tray and to convey overflow liquid into the end of the next lower tray. Conduits 55 of coil 54 rest upon the bottom of the tray 44″. These conduits may be grooved on their outer surfaces, as shown in Fig. 5, to provide for wetting of the outer surface of the conduits by capillary action or any other means such as wicks or the like may be provided for wetting the outer surface of these conduits. In the operation of this embodiment of my invention liquid refrigerant flows from the flash chamber, as before, into one end of the uppermost of the trays, the trays being level, the refrigerant spreads out covering the bottom of the tray. This refrigerant is picked up by the capillary grooves or other means for wetting the exterior surface of conduits 55, and excess refrigerant overflows through tube 63 into one end of the next lower tray wherein the refrigerant spreads out in this lower tray wetting the conduits resting upon the bottom thereof, and as before, liquid overflows from the opposite end of this tray and so on serially into the lower trays.

While I have illustrated and described but three specific modifications of my invention and have incorporated the invention in a particular type of refrigerating system, the invention obviously may take other forms and be variously applied. The invention is, therefore, limited only by the following claims.

What is claimed is:

1. A heat exchange device comprising a horizontal tray, means for maintaining a shallow pool of liquid refrigerant on the bottom of said tray, a horizontal heat exchange coil disposed within said tray with the bottom surface thereof resting upon the bottom of the tray, means for flowing a medium to be cooled through said coil, and capillary grooves formed of metal as an integral part of the outer surface of the coil for lifting liquid refrigerant from the tray onto the coil whereby a film of liquid refrigerant is formed thereon, which film is vaporized by heat supplied from the medium flowing through the coil thereby cooling said medium.

2. A heat exchange device comprising a shallow horizontal tray provided with a transversely disposed distributing trough on one end thereof and a plurality of longitudinally disposed troughs opening into said distributing trough and projecting to the opposite end of said tray, a horizontal pipe coil disposed within said tray with bottom portions thereof arranged within each of the longitudinally disposed troughs, means

connecting said pipe coil to a secondary heat transfer system for flow of secondary heat transfer medium therethrough, means forming capillary passages on the outer surface of said pipe coil, and means for supplying a primary liquid refrigerant to said distributing trough, the construction and arrangement being such that primary liquid refrigerant supplied to the distributing trough flows therefrom into the longitudinally disposed troughs beneath and in contact with the bottom of the pipe coil, which refrigerant is picked up by the capillary passages on the outer surface the pipe coil forming a film of liquid refrigerant on said surface which film is vaporized by heat supplied by the secondary heat transfer medium flowing through the pipe coil thereby cooling said medium.

3. A heat exchange device as set forth in claim 2 wherein the longitudinally disposed troughs are V-shaped in cross section.

4. A heat exchange device as set forth in claim 2 wherein the longitudinally disposed troughs are arcuate in cross section.

5. A heat exchange device comprising an outer shell, a plurality of horizontal trays disposed in vertical spaced relation within said shell, a plurality of horizontal pipe coils arranged in said shell with one of such coils located in each of said trays, means connecting said pipe coils to a secondary heat transfer system for flow of secondary heat transfer medium therethrough, means for supplying a liquid refrigerant to the uppermost of said trays, means for flowing liquid refrigerant from the uppermost of said trays into and across the remaining trays in series whereby each of said trays is provided with shallow pools of liquid refrigerant, and means on the outer surface of said pipe coils for lifting liquid refrigerant from said trays onto said pipe coils whereby the outer surface of the pipe coils is covered with a film of liquid refrigerant, which film is vaporized by heat supplied by the secondary heat transfer medium flowing through the pipe coils thereby cooling the medium.

6. A heat exchange device as set forth in claim 5 in which each of the plurality of trays is provided with a flat bottom upon which the pipe coils rest.

7. A heat exchange device as set forth in claim 5 in which each of the plurality of trays is provided with a transversely disposed distributing trough at one end thereof and a plurality of V-shaped troughs opening into and projecting from said distributing trough to the opposite end of the tray, and in which the bottom portion of the pipe coils rest within the V-shaped troughs.

8. A heat exchange device as set forth in claim 5 in which each of the plurality of trays is provided with a corrugated bottom and with a transversely disposed distributing trough at one end thereof, and in which the bottom portion of the pipe coils rest within the corrugated bottom of the trays.

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