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G. C. RANNENBERG ETAL

3,170,303

SUBLIMATOR

Filed Aug. 20, 1963

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FIG. 1

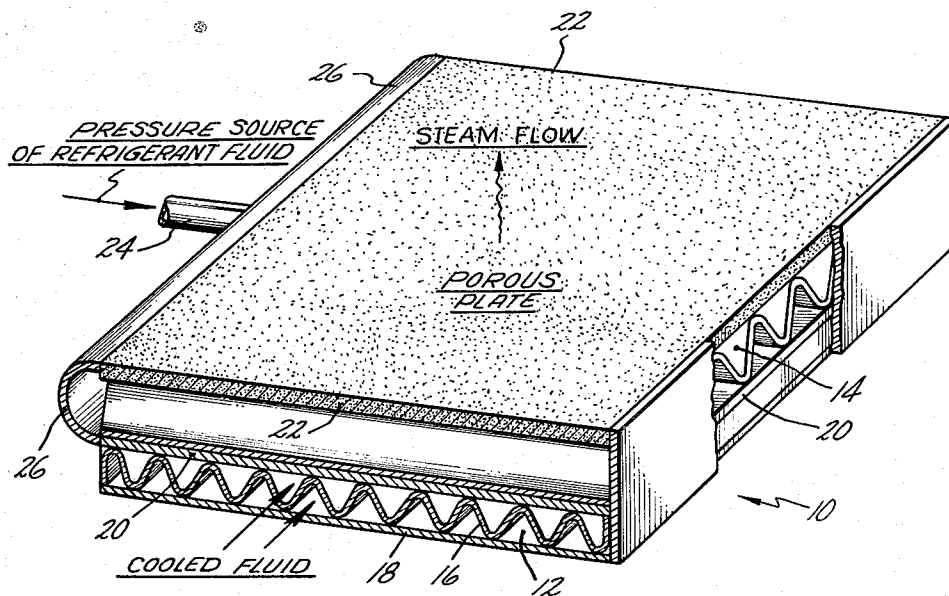
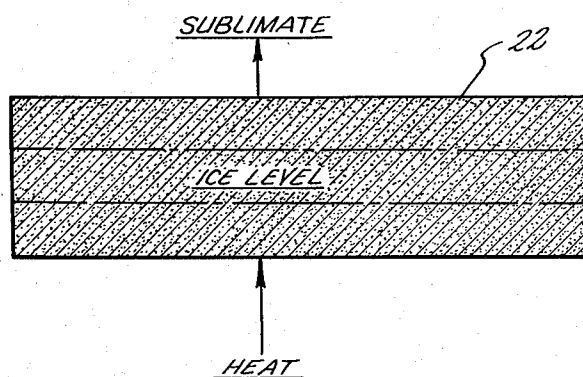


FIG. 2



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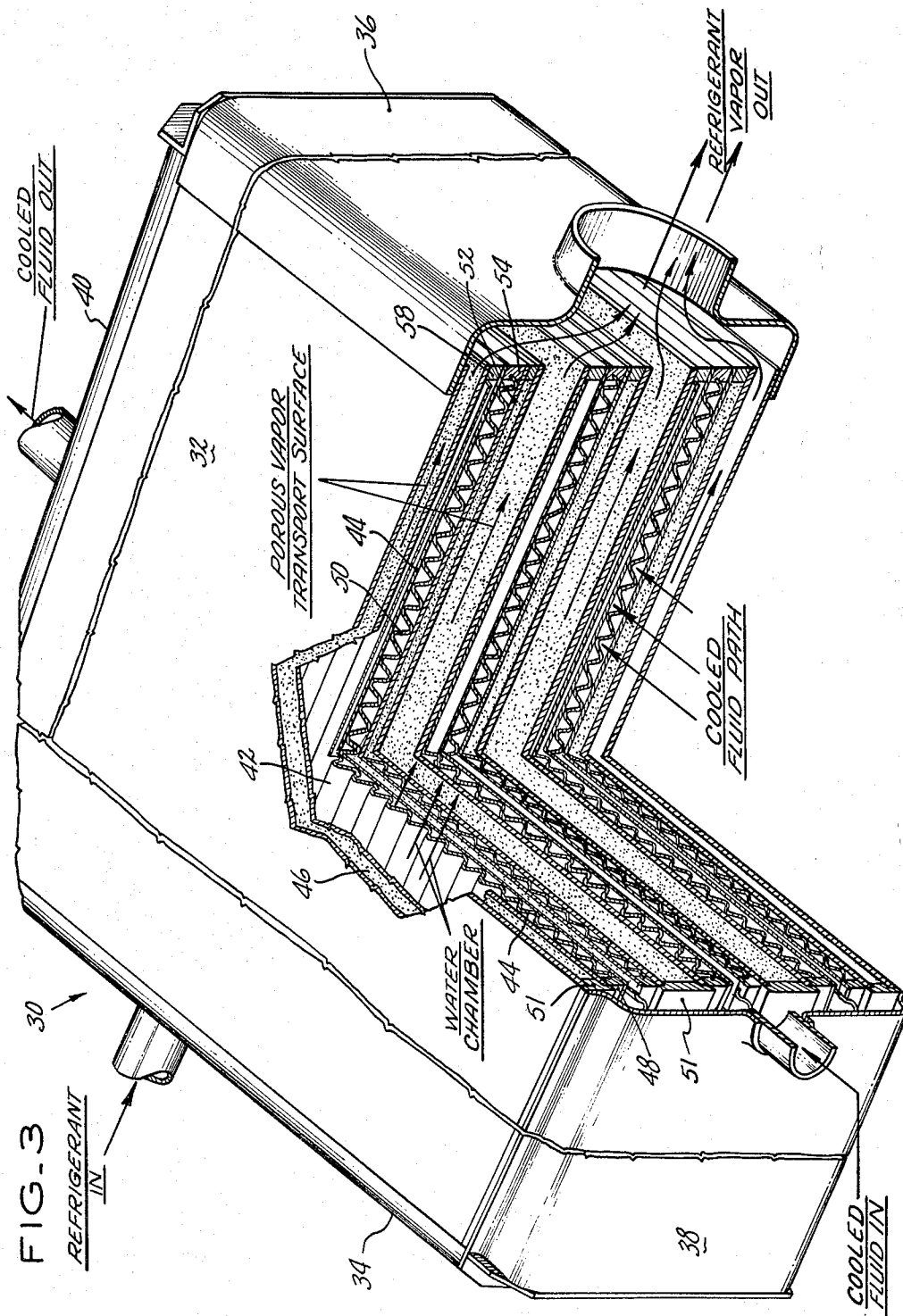
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3,170,303 SUBLIMATOR

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Filed Aug. 20, 1963, Ser. No. 303,382
11 Claims. (Cl. 62-64)

This invention relates to heat exchangers and particularly to sublimators wherein a fluid or surface intended to be cooled transfers its heat to a refrigerant which is sublimated.

It is an object of this invention to provide a heat exchanger comprising a porous member for receiving a liquid refrigerant and having a surface subjected to an atmosphere whose pressure is at a value wherein the refrigerant will sublimate.

Another object of this invention is to provide a chamber in a heat exchanger for receiving refrigerant, which chamber has a wall formed from a porous material containing a surface subjected to a pressure at or below the triple point of the refrigerant.

A still further object of this invention is to provide a cooling system which is characterized as being relatively simple to construct, economical to manufacture, is self-regulating, automatic and highly reliable but yet capable of rugged use.

A still further object of this invention is to provide a heat exchanger of the sublimator type having a supply of refrigerant at a constant pressure and fed into the heat exchanger as a function of the demands of the heat exchanger without the use of metering devices, sensors and the like.

A still further object of this invention is to provide a means of utilizing an expendable refrigerant in a highly efficient manner, that is, with little or no loss through carry-over of liquid refrigerant.

Other features and advantages will be apparent from the specification and claims and from the accompanying drawings which illustrate an embodiment of the invention.

FIG. 1 is a perspective view partly in cross section illustrating the invention.

FIG. 2 is an enlarged cross-sectional view of the porous plate.

FIG. 3 is a perspective view partly in cross section illustrating another embodiment of the invention showing a number of elements grouped together to produce a large capacity device.

Heat exchangers of the water boiler class are generally well known in the art and essentially comprise a heat exchanger core which may store refrigerant therein or refrigerant may be fed thereto. The fluid medium intended to be cooled is then passed through the heat exchanger either in direct or indirect heat exchange relation for transferring the heat to the refrigerant. The refrigerant then absorbing this heat changes state; namely, boils off and is vented to atmosphere or ambient. In applications, particularly in aircraft or outer space applications, where it is necessary to assure proper cooling in a most efficient manner, it is customary to control the amount of refrigerant to maintain the temperature of the fluid medium intended to be cooled at its desired value. This entails the utilization of valving and sensing mechanism resulting in a relatively complex temperature control system. We have found that a properly designed heat exchanger utilizing our invention can be made to operate in an efficient manner without using any sensing and valving mechanism.

While this invention is somewhat like a water boiler, it is in fact considered by those skilled in the art to be a sublimator. However, it is to be understood that the

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terminology selected in no way limits the scope of this invention.

This invention is particularly applicable where the refrigerant used has a triple point, that is, where equilibrium of vapor, liquid and solid will occur at a predetermined temperature or pressure and that there is available an environment at or below this condition. The refrigerant which may be water, while not limited thereto, is directed to the heat exchanger from a pressurized source, which heat exchanger defines a chamber for receiving the refrigerant. One area of the chamber contains a porous or sintered material having a surface exposed to this environment. The refrigerant passing through the porous material freezes when exposed to the low pressure of this environment thus limiting refrigerant flow there-through and eventually blocking it off. The refrigerant sublimates into this environment as heat is conducted to the porous plate by virtue of being in indirect heat exchange relation with the fluid medium intended to be cooled. As the refrigerant sublimates away from the plate and the solid refrigerant becomes depleted, more refrigerant automatically is fed into the plate.

The operation of this invention may best be explained by considering that the porous member contains a large number of closely packed passages. Each passage may undergo a cycle as follows:

Beginning with a solid plug of ice in the passage, sublimation occurs at the surface exposed to space, and, as a result, subcools the walls of the passage. When the thickness of the ice layer is reduced until it can no longer support the internal pressure in the boiler, water begins to flow through the passage to space. When the liquid water sees pressure below its triple point and encounters the subcooled passage walls, it freezes, reforming the plug and completing the cycle. Although operation of a single passage is cyclic, operation of the gross porous plate is continuous.

Now referring to FIG. 1 and FIG. 2 which generally show a heat exchanger generally indicated by numeral 10 comprising a lower layer 12 and adjacent upper layer 14. The lower layer contains continuous ruffled fin 16 sandwiched between end plate 18 and intermediate plate 20. It will be noted that the corrugated fin together with the adjacent plates define a series of parallel conducting passages for receiving hot fluids intended to be cooled. The adjacent layer may comprise similar ruffled fins sandwiched between the intermediate plate 20 and the upper plate 22. Refrigerant is fed to the chambers defined by the ruffled plate together with the porous plate 22 and intermediate plate 20 through inlet line 24 which feed header 26 and in turn directs refrigerant to the various chambers defined in layer 14. In this embodiment, the porous plate overlies the entire surface of the layer 14 and is subjected to an atmosphere whose pressure will cause the refrigerant to freeze. It will be understood by those skilled in the art that the particular shape and configuration of the heat exchanger can take any form, depending on the particular application for which it is to be used.

As viewed in FIG. 2, as the refrigerant enters into the porous plate and comes into contact with this low pressure environment, the refrigerant changes state from a liquid to a solid causing ice to form in the pores of the sintered material. We have found that the ice substantially forms a uniform sheet extending completely across the porous material. This ice sheet serves to prevent the flow of refrigerant through the porous plate. The ice sublimates to the low pressure environment, depleting the ice in the porous plate and hence changing its dimensions. This automatically causes additional refrigerant to flow into the porous plate for replacing the

amount depleted. Consequently, the amount of refrigerant sublimated to atmosphere is replenished by automatically receiving additional refrigerant fluid from the pressurized source. This results in a self-regulating, simple type of sublimator.

An example of the conditions of a sublimator used to cool glycol and using water as a refrigerant is presented hereinbelow, but is included herein merely to set forth one such example and in no way is intended to limit the scope of the invention.

- (a) The porous plate is constructed from a filter material composed of 300 series stainless steel having a pore size of $\frac{1}{2}$ micron.
 - (b) The glycol is fed into the heat exchanger core at 60° F.
 - (c) The feed water pressure is at 10 p.s.i.a. (absolute)
 - (d) The low pressure source=200 microns vacuum
- $$(e) \quad \frac{Q \text{ B.t.u./hour}}{A \text{ ft.}^2 \text{ (porous plate)}} = 1700$$

FIG. 3 is an exemplary showing of another embodiment of this invention where the sublimator is generally indicated by numeral 30 comprising core 32, feed water inlet header 34, exit header 36, fluid intended to be cooled, inlet header 38 and its exit header 40. As noted from the drawing, suitable piping is connected to each header in any well-known manner.

The core is made by alternately stacking passes so that a refrigerant (water) layer is in juxtaposition with a layer of fluid intended to be cooled. Each layer or pass of the core may be constructed in the conventional manner save for the fact that a porous plate overlies each of the refrigerant passes. As refrigerant is fed into the feed header 34 it passes through the plurality of refrigerant passes. Since all of the refrigerant passes are similarly constructed, for the sake of convenience and to facilitate in the explanation of this invention, only one refrigerant pass and one fluid-intended-to-be-cooled pass will be described. The refrigerant pass comprises a continuous ruffled fin 42 made from any suitable material such as stainless steel extending the length and width of the core and sandwiched between intermediate plate 44 formed from a suitable highly heat conductive material and porous plate 46 constructed from any suitable sintered or porous material, but preferably having good heat conductivity properties. A pair of closure members 48 (only one is shown) is mounted adjacent opposite the ends of the ruffled fins and a pair of closure members 51 (only one being shown) is mounted adjacent the porous plate. The porous plate 46 overlies the ruffled fins and as water tends to migrate through the pores it will come in contact with the low pressure environment to which it is exposed by virtue of the opening of the outlet header 36. It will be noted that another closure plate 58 is mounted at the end of fin element 42 adjacent the exit header to prevent water from escaping into the exit header.

The pass for the fluid intended to be cooled is likewise constructed from continuous fin element 50, sandwiched between intermediate plates 44 and 52. A pair of closure plates 54 (only one being shown) closes off the end thereof. It will be noted that the series of passages defined by ruffled fin 50 and the intermediate plates 44 and 52 pass fluid in a direction transverse to direction of the passages defined by ruffled fin 42 and its associated intermediate plates.

The operation of sublimator 30 is identical to the operation of sublimator shown in FIG. 1. As water refrigerant is admitted to the core through the various refrigerant passes it will migrate through the pores of that porous plate and owing to the fact that it is subjected to a low pressure, on contact it freezes. This forms a layer of ice extending across the porous plate preventing water from discharging. The fluid intended to be cooled passing adjacent the water pass transmits

heat through the fins, intermediate plate, through the water and eventually into the porous plate. This heat causes the ice to sublime which sublimation occurs at a rate directly proportional to the heat load. The fluid intended to be cooled passes through the heat exchanger giving off heat as described above and being discharged at a temperature lower than it entered.

It is to be understood that the invention is not limited to the specific embodiment herein illustrated and described, but may be used in other ways without departing from its spirit.

We claim:

1. Means for automatically self-regulating refrigerant flow from a supply of refrigerant into a heat exchanger comprising a porous plate having a pore size whose magnitude is such that the porous plate is relatively impervious to the flow of liquid under normal operating pressure mounted between the refrigerant and a substantially low pressure source whose pressure is below the triple point of the refrigerant, said porous plate being capable of holding the refrigerant in its solid state for defining a closure between the refrigerant in its liquid form and the low pressure source, means for conducting heat from a medium intended to be cooled to said solid refrigerant for causing said solid refrigerant to sublime in said low pressure source, whereby said refrigerant is automatically supplied to said porous plate to replenish the solid refrigerant sublimated to said low pressure source.

2. A sublimator comprising a pair of chambers, a heat transfer surface forming a side of the first of said chambers, said first of said chambers containing a fluid to be cooled, the second of said chambers containing a refrigerant fluid, a porous wall having pore openings in the order of $\frac{1}{2}$ micron forming one side of said second chamber remote from and parallel to the first chamber, said porous wall forming a path for refrigerant fluid to flow from the inside to the outside of said refrigerant chamber, a pressure on the outside of said porous wall sufficiently low to maintain the refrigerant fluid in said porous wall in its solid state, and means for supplying refrigerant to said second chamber.

3. Apparatus for cooling a fluid or surface by a refrigerant having a triple point comprising a chamber for receiving said refrigerant, a porous plate having a pore size in the order of $\frac{1}{2}$ micron forming a wall surface of said chamber and having one face thereof subjected to a low pressure environment at or below said triple point, said porous plate exuding refrigerant to the low pressure environment whereby said refrigerant upon contact therewith solidifies in said porous plate, said chamber being located adjacent the fluid or surface intended to be cooled so that heat absorbed by said refrigerant sublimates said solid refrigerant to the low pressure environment, a source of refrigerant including connection means leading refrigerant to said chamber.

4. An automatic, self-regulating sublimator comprising a source of water, a chamber, means interconnecting said source and said chamber for continuously feeding water thereto, a porous member forming a wall of said chamber and in contact with said water defining a path for conducting water to flow from the inner surface to the outer surface thereof, said outer surface being subjected to a low pressure source whose pressure is below the triple point of the water so that upon contact with said low pressure source said water freezes in said porous member, and a medium intended to be cooled located adjacent said chamber, an open ended chamber having a heat transfer surface disposed parallel to and opposite said porous member for receiving said medium, means between said porous plate and said heat transfer surface to conduct heat from one to the other whereby heat conducted from said medium is absorbed by the frozen water causing said water to sublime to said low pressure source.

5. A self-regulating sublimator having a first chamber adapted to receive fluid intended to be cooled, an adjacent second chamber adapted to receive a refrigerant, having a triple point, in its liquid state, a low pressure source whose pressure is below the triple point of the refrigerant, a porous plate formed from a sintered material having a pore size in the order of $\frac{1}{2}$ micron defining one of the walls of said second chamber mounted between said chambers and said low pressure source defining a flow path from the inner to outer surface of said porous plate, said porous plate holding said refrigerant in its solid state when subjected to said low pressure for defining a sheet of solid refrigerant extending the length and width of the porous plate for blocking off the flow of said liquid refrigerant through said porous plate to said source, wall means disposed parallel to said porous plate formed from conductive material between said first and second chambers for transferring heat to said solid refrigerant from said fluid intended to be cooled to cause said solid refrigerant to sublime to said low pressure source, and means for conducting liquid refrigerant to said porous plate.

6. The process of cooling a fluid or surface comprising the steps of conducting a refrigerant having a triple point to a porous plate having a pore size in the order of $\frac{1}{2}$ micron pervious to said refrigerant, passing the refrigerant through said porous plate, subjecting said refrigerant to a pressure at or below the triple point of said refrigerant so that said refrigerant freezes therein, and placing said refrigerant adjacent said fluid or surface intended to be cooled whereby heat is transferred from said fluid or surface causing said frozen refrigerant to sublime.

7. Apparatus for automatically self-regulating refrigerant flow from a supply of refrigerant into a heat exchanger comprising a porous member having its pore sizes in the order of $\frac{1}{2}$ micron mounted between the refrigerant and a substantially low pressure source whose pressure is below the triple point of the refrigerant, said porous member being capable of holding the refrigerant in its solid state for defining a closure between the refrigerant in its liquid form and the low pressure source, means including a heat transfer surface disposed parallel to said porous plate for conducting heat from a medium intended to be cooled to said solid refrigerant for causing said solid refrigerant to sublime in said low pressure source, whereby said refrigerant is automatically supplied to said porous member to replenish the solid refrigerant sublimated to said low pressure source.

8. Apparatus as defined in claim 7 wherein said refrigerant is water.

9. Apparatus as defined in claim 7 wherein said means also includes a fin element disposed between said porous member and said heat transfer surface.

10. Apparatus as defined in claim 7 wherein said porous member is formed from a metallic material.

11. Apparatus as defined in claim 7 wherein said porous member is formed from stainless steel.

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