Oct. 17, 1933. L. A. PHILIPP 1,931,268

REFRIGERATING SYSTEM

Filed April 7, 1931 2 Sheets-Sheet 1

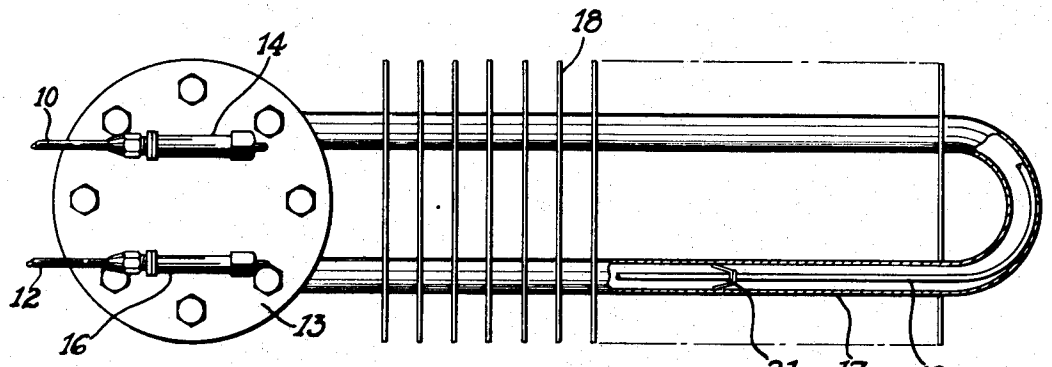


Fig 1

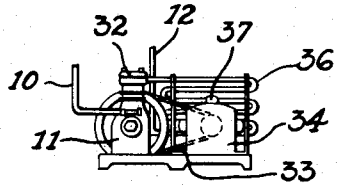


Fig 6

Fig 2

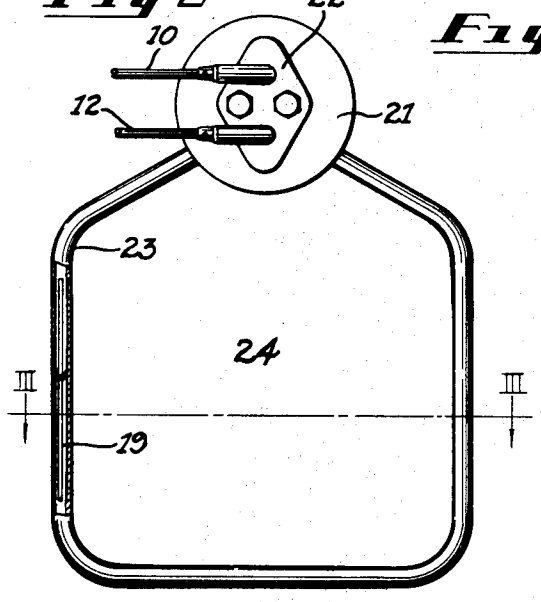
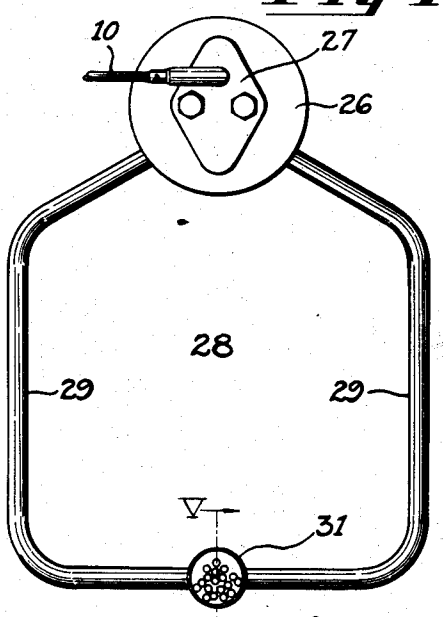


Fig 4



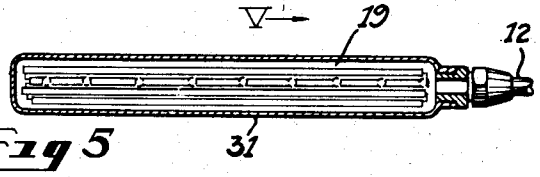


Fig 5

Fig 3

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Oct. 17, 1933. L. A. PHILIPP 1,931,268

REFRIGERATING SYSTEM

Filed April 7, 1931 2 Sheets-Sheet 2

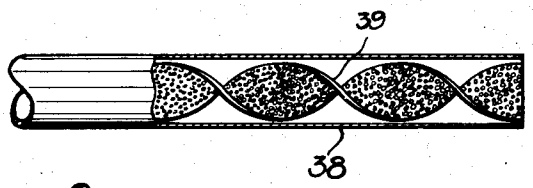


Fig 6a.



Fig 10

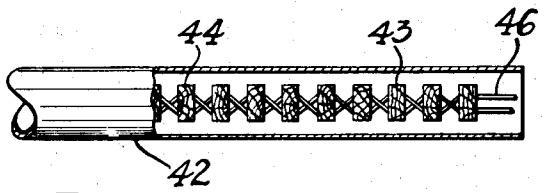


Fig 7



Fig 11

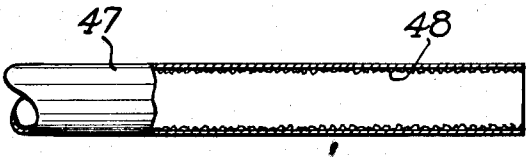


Fig 8

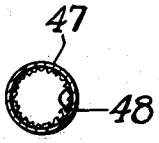


Fig 12

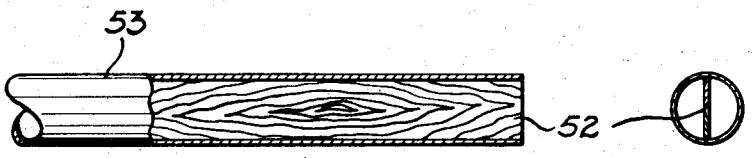


Fig 9

Fig 13

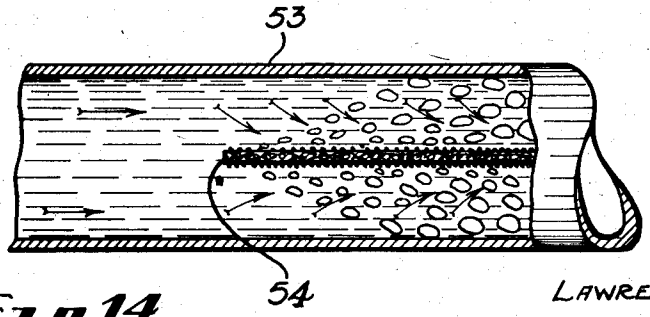


Fig 14

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1,931,268

REFRIGERATING SYSTEM

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Application April 7, 1931. Serial No. 528,355

11 Claims. (Cl. 62—126)

This invention relates to refrigerating systems and has particular relation to refrigerating systems in which a volatile liquid is vaporized in a heat exchange device commonly known as a refrigerant evaporating unit.

An object of the invention is to provide a refrigerating system in which all of the liquid contained in a refrigerant evaporating unit thereof will be maintained at a temperature corresponding to the pressure in the vapor space above the liquid.

Another object of the invention is to prevent the superheating of liquid contained in a refrigerant evaporating unit of a refrigerating system and thus to provide an evavorating unit all portions of which are maintained at substantially a uniform temperature.

Another object of the invention is to prevent violent periods of boiling of the liquid contained in a refrigerant evaporating unit of a refrigerating system, which periods of violent boiling cause a wide variation in the vapor pressure of the low side of the system.

Prior to the invention one of the most troublesome difficulties in the construction and operation of a refrigerating system has been the fact that the liquid employed in an evaporating unit could not at all times be made to boil or vaporize at a temperature corresponding to the vapor pressure in the unit. In evaporators with symmetrical depending tubes, for example, it has been found that there exists a wide difference between the temperature of a portion of the evaporator adjacent the liquid level and some other portion thereof (the bottom of a tube, for example) which is remote from the liquid level. Theoretically, of course, the temperature of all portions of such evaporator should be approximately the same, inasmuch as all of the heat absorbed, above a temperature corresponding to the vapor pressure therein, should be employed in vaporizing liquid rather than in increasing the sensible heat of the liquid. Numerous experiments have indicated that this uniform temperature throughout the liquid can be maintained only when vaporization occurs throughout substantially the entire extent of the liquid but not if vaporization occurs only at the surfaces thereof.

It is well known, for example, that water will boil at atmospheric pressure at approximately 212° F. but it is also known that such water when placed in a vessel and heated, will reach a temperature considerably greater than 212° before it visibly boils. However, it does boil at the urface. The heat causing this surface boiling cannot be provided without a difference in temperature in the liquid in view of which fact the liquid below the surface is superheated to a temperature considerably higher than that at the surface.

This surface boiling continues in this manner for some little time, by the conduction or convection of heat from the bottom of the vessel through the liquid, until finally, a vapor bubble is formed at the bottom of the vessel in the region of the liquid of highest temperature. This bubble immediately provides a nucleus for the formation of other bubbles which enlarge and multiply very rapidly, due to the fact that they are confined in a liquid, the temperature of which is much greater than the temperature at which boiling naturally would occur at that pressure. The formation of such bubbles quickly reduces the sensible heat of the liquid with which they are surrounded and a continuous formation of bubbles thereafter causes a substantially uniform temperature throughout the entire extent of the liquid.

This same phenomenon of superheating of liquid occurs with practically all liquids which are now employed as refrigerants, the only difference being that such refrigerant liquids superheat before boiling to a far greater extent than does water. Some evaporators, for example, which are widely employed in the construction of refrigeration apparatus, do not boil liquid to any large extent except on the surface, and in these the temperature of the evaporator in all regions remote from the surface is much greater than is the temperature adjacent thereto. Naturally, under such circumstances, it is necessary to operate these evaporators at a much lower pressure than could be employed if the liquid were made to boil throughout its entire extent rather than at the surface.

This invention contemplates the employment of some relatively porous material which is disposed in the liquid beneath the upper surface thereof and which serves as a nucleus on which vapor bubbles readily are formed. This stimulation of the vaporization of liquid provides for the change of state of the liquid into a gas at practically the same temperature at which the change would occur on the surface of the liquid, and prevents the temperature of the liquid from increasing above a point corresponding to the proper temperature at which liquid theoretically should boil at the pressure obtaining in the evaporator.

Now even in an evaporator constructed according to the principles of this invention, it is to be

observed that liquid ordinarily does not boil around the surface of the container in which it is located, but boils only from the surface of the device or ebullator which is immersed within the liquid. It is believed that this is accounted for by the fact that the interfacial tension between the ebullator and the liquid surrounding it is materially less than the interfacial tension between such liquid and the evaporator in which it is contained.

For example, it is apparent that if the interfacial tension between the evaporator and the liquid is relatively high, or, in other words, if there is a pronounced tendency for the liquid to adhere to or wet the surface of the evaporator, then it will be difficult for vapor bubbles to be formed between the surface of the liquid and the surface of the evaporator. If this resistance to the formation of vapor between the liquid and the interior surface of the evaporator is greater than the resistance to the formation of bubbles at the surface of the liquid, it is apparent that the liquid will superheat beneath the surface. When, however, an ebullator is placed in the superheated liquid beneath the surface thereof between which ebullator and the liquid the interfacial tension is less than the interfacial tension between the liquid and the surface of the evaporator, the superheated liquid will immediately boil below the surface and adjacent the ebullator.

A theoretically perfect ebullator would be one having an interfacial tension with liquid which was no greater than the interfacial tension between the liquid and its own vapor above the surface. Such ebullator when inserted into the liquid would practically extend the surface downwardly as far as the ebullator projected. If such ebullator were projected entirely to the bottom of the liquid, it is apparent that boiling would occur at the bottom as readily as it would occur on the surface.

Generally, however, there is what is known as an induction period during which vapor bubbles are not formed around the ebullator until after a certain amount of superheating has occurred beneath the surface. Within a short time, however, vapor bubbles begin to be formed on the ebullator and thereafter they are formed continuously during the application of heat and maintain the temperature of liquid substantially constant throughout.

In an evaporator without such ebullator, however, the induction period is relatively long, or in other words, no bubbles are formed in the liquid beneath the surface for a considerable period of time until the liquid has superheated sufficiently to overcome the interfacial tension between the liquid and the surface of the evaporator. When such degree of superheating, however, is reached, there is such an excess of heat in the liquid, over that which would prevail if the liquid had not superheated, that a violent period of boiling occurs. When this period of boiling has continued for a sufficient length of time to reduce the sensible heat of the liquid until the temperature thereof corresponds to the vapor pressure at which the liquid should boil, the formation of bubbles is entirely discontinued. Thereafter there is no boiling beneath the surface until a similar explosive boiling period occurs at the end of a preceding induction period.

Such irregular operation of an evaporating unit obviously greatly affects the efficiency of a refrigerating system in which it is employed for the reason that during the violent periods of boiling the vaporization of liquid occurs at a much greater rate than when it is boiling only from the surface. Inasmuch as a condensing unit, which exhausts the refrigerant vapor from an evaporating unit, has a constant capacity for withdrawing refrigerant therefrom, it is apparent that the vapor pressure will not be decreased uniformly unless the rate of vaporization of liquid proceeds uniformly and the suction pressure of the refrigerating system will vary accordingly. It is often difficult, if not impossible, to control the operation of a refrigerating system by means of the suction pressure thereof under conditions such as this.

For a better understanding of the invention reference may now be had to the accompanying drawings forming a part of this specification, in which:

Figure 1 is a side elevational view partly in cross section of a refrigerant evaporating unit having an ebullator positioned therein according to the principles of this invention;

Figure 2 is an end elevational view partly in cross section of another form of evaporating unit illustrating a different arrangement of an ebullator operated in accordance with the principles of the invention;

Figure 3 is a cross sectional view taken substantially along line 3—3 of Figure 2 and illustrating the arrangement of a plurality of ebullators in the tubes of which the evaporator is formed;

Figure 4 is an end elevational view, illustrated partly in cross section, of a slightly different form of refrigerant evaporating unit in which ebullators are employed;

Figure 5 is a cross sectional view of a portion of the evaporator illustrated by Figure 4 taken substantially along line 5—5 thereof and illustrating a longitudinal view of the ebullators as employed in that structure;

Figure 6 is a diagrammatical view of a refrigerant condensing unit which may be employed in conjunction with any of the refrigerant evaporating units disclosed herein to provide an operable refrigerating system;

Figures 6*a*, 7, 8 and 9 are longitudinal sectional views of tubes employed in refrigerant evaporating units and embracing other forms of ebullators constructed according to the principles of the invention;

Figures 10, 11, 12 and 13 are cross sectional view of the structures disclosed by Figures 7, 8 and 9;

Figure 14 is a fragmentary view of a tube or other portion of a refrigerant evaporating unit which illustrates the vaporization of liquid around an ebullator employed therein.

In practicing the invention any suitable refrigerant evaporator may be employed, as, for example, the conventional evaporators illustrated in the drawings by Figures 1 to 5. Each of these evaporators comprises a suction line 10 which is adapted to be connected to the low side of a condensing unit 11 illustrated by Figure 6 and a liquid line 12 which supplies liquid to the evaporator from the high side of the aforesaid condensing unit.

The evaporator illustrated by Figure 1 comprises a reservoir or header 13 to which the suction and liquid lines 10 and 12 are connected by suitable service valves 14 and 16. A plurality of refrigerant circulating tubes or loops 17 are connected at their opposite ends along the length of the header 13 in parallel and aligned relation and on these loops are secured perpendicularly a plu-

rality of spaced and vertically disposed heat absorbing fins 18. A refrigerant liquid ebullating device 19, or other suitable means for assisting in the vaporization of the liquid contained in the evaporating unit, is employed in one or more of the tubes 17 and is secured therein by means of a spring 21 which is compressed between the walls of the tube and clamped against the ebullator to maintain the latter in proper position within a loop. The liquid level in such evaporating unit ordinarily is maintained in the region of the upper legs of the horizontally disposed loops 17.

The refrigerant evaporator illustrated by Figure 2 comprises a header or refrigerant containing vessel 21 having a single manifold fitting 22 through which the suction and liquid lines 10 and 12 communicate with the interior of the header. A plurality of refrigerant containing loops 23 are connected to the header along the lower surface thereof and provide therebeneath a freezing compartment 24 which may be employed for any purpose desired. An ebullating device 19, of the type employed in the evaporator disclosed by Figure 1, is secured by a spring 21 in one of the vertical legs of each loop and it is preferable when a plurality of such devices are employed, to insert them alternately in vertical legs on opposite sides of the header. Each of the ebullators provides a nucleus upon which vapor bubbles are formed more readily than elsewhere in the evaporating unit and with this arrangement of the ebullators in one leg of each loop and in opposite legs of succeeding loops, the circulation of liquid is in opposite directions in each succeeding loop.

The structure disclosed by Figure 4 embraces a header 26 and a fitting 27 secured thereto for the reception of the suction line 10, all of which elements are similar to the header 21 and fitting 22 employed in the structure disclosed by Figure 2 except that the liquid line 12 is not attached to the fitting in this structure. A freezing compartment 28 is provided beneath the header 26 by two rows of spaced conduits which are connected at opposite ends to the header 26 and to an auxiliary header 29 arranged directly beneath the former. The auxiliary header 29 receives a plurality of ebullators 19 of any suitable type such as those employed in the structures disclosed by Figures 1 to 3 and these tend to promote vaporization of liquid adjacent the lower extremity of each of the tubes 29. The liquid line 12 from the condenser unit 11 is connected to one end of the auxiliary header 31 and supplies liquid thereto in the immediate vicinity of the ebullators 19.

In the evaporators disclosed by both Figures 2 and 4 the liquid level is maintained in a region below the suction line 10 but above the tubes depending from the header, in which event the ebullators 19 will always remain immersed in the liquid.

The condensing unit disclosed by Figure 6 embraces a refrigerant compressor 32 which is driven by an electrical motor 34 through a belt 33. Compressed refrigerant is discharged from the high side of the compressor into a condenser 36 from which refrigerant in liquid form is supplied to any of the evaporating units disclosed, through the liquid line 12. A fan 37, also driven by the motor 34, discharges a blast of air against the surface of the condenser 36 thus enabling the latter to provide liquid for the operation of the system at a relatively low head pressure. It is to be understood that such a condensing unit has here been employed only for the purpose of illustration and that any other means for supplying liquid in a refrigerating system may be employed.

The ebullators 19 illustrated in the evaporators disclosed by Figures 1 to 5 consist of relatively long strips of reed or other flexible fibrous material having a relatively low interfacial tension when submerged in refrigerant liquid such as methyl chloride, sulphur dioxide, ammonia, ethyl chloride, etc. At the beginning of a period of operation of any refrigerating machine employing these or other similar liquids, ebullators of this character not only initiate vaporization of liquid sooner than it might otherwise occur but they provide a nucleus for the vaporization of liquid thereafter at a relatively continuous rate and without an appreciable superheating of the liquid by which they are surrounded. During such periods of vaporization the vapor bubbles will be formed almost exclusively on the surface of the ebullators inasmuch as the interfacial tension between such ebullators and the liquid is less than the interfacial tension between the liquid and the evaporator in which it is contained. Naturally vaporization will always occur in the region where there is the least resistance to the formation of bubbles.

The structure disclosed by Figure 6*a* comprises a section of a tube 38 for containing refrigerant liquid and in which is contained a twisted metallic or other suitable member 39 having its opposite surfaces covered with sand, silica gel, porcelain, antimony, zinc, spelter, mossy zinc or slag. These materials may be made to adhere to the surface of the member 39 by fusion or if preferable the entire ebullator may be constructed therefrom.

Figure 7 discloses another liquid containing tube 42 suitable for employment in a refrigerant evaporating unit, and in which is inserted an ebullator 43 consisting of a plurality of wooden or other fibrous buttons 44 which are strung on a pair of twisted wires 46.

Figure 8 illustrates another tube of a refrigerant evaporating unit the interior surface of which is coated with a layer of material 48 such as any of the materials referred to in the discussion of the structure disclosed by Figure 6.

In the structure disclosed by Figure 9 a wooden or other fibrous stick 52 is inserted in the interior of a liquid containing refrigerant evaporating tube 53.

The structure disclosed by Figure 14 illustrates a liquid filled refrigerant evaporating tube 53 in which an ebullator 54 of any of the several types disclosed herein is immersed. As indicated by this figure, the liquid, circulating in the tube 53, in the direction indicated by the arrows, does not boil before reaching the ebullator 54 but merely increases in sensible heat under the influence of the heat conducted from the surrounding medium through the tube 53. When such superheated liquid arrives in the vicinity of the ebullator some of it vaporizes due to the fact that the interfacial tension between the liquid and the ebullator is lower than with any other part of the evaporator with which it previously has contacted. When once the vaporization of liquid is initiated on the ebullator, the vapor bubbles enlarge to such an extent that they are carried away by the liquid and thereafter become distributed throughout the entire cross sectional area of the tube where they are further enlarged by the adsorption of heat conducted through the

tube from the surrounding heated medium. When these bubbles eventually arrive at some vertically disposed portion (not shown) of the tube, they provide an upwardly directed force tending to carry the liquid with them. This upward movement of bubbles in a tube of relatively small cross sectional dimension creates a positive movement of the liquid in any portion of an evaporator not so effected.

In the evaporators disclosed by Figures 1 and 3, for example, liquid will circulate upwardly in the portions thereof through which the vapor formed on the ebullators 19 will rise to the headers 13 and 21 and downwardly elsewhere.

In the structures disclosed by Figures 2 and 3, the liquid will circulate alternately in opposite directions in each succeeding loop of the evaporator.

The invention is not limited to the particular forms and applications thereof which are hereinbefore specifically illustrated, but has numerous other forms and applications within its spirit and scope as defined by the appended claims.

I claim:

1. A refrigerating system comprising an evaporating unit having a quantity of refrigerant liquid confined therein, and means comprising a flexible reed of capillary structure for preventing the superheating of refrigerant liquid beneath the surface thereof.

2. A refrigerating system comprising a refrigerant evaporator having a quantity of refrigerant liquid confined therein, and a piece of wood of capillary structure submerged within the liquid for initiating the formation of vapor bubbles below the level of the liquid refrigerant.

3. A refrigerating system comprising a refrigerant evaporating unit having a plurality of tube loops associated therewith, means in alternate legs only of succeeding loops of the evaporator for initiating the formation of vapor bubbles therein, and means for maintaining said first named means in definite positions within said legs.

4. A refrigerating system comprising an evaporator having a quantity of liquid refrigerant therein and ebullition means comprising a piece of wood whose surfaces which contact with said refrigerant liquid have a lower interfacial tension with said liquid than between the liquid and the liquid engaging surfaces of the evaporator for initiating the formation of refrigerant vapor beneath the surface of the liquid.

5. A refrigerating system comprising an evaporator having duct means containing a quantity of liquid refrigerant and a relatively slender non-metallic ebullition initiator within one of said duct means and whose cross sectional area is considerably smaller than the cross sectional area of said duct means and whose surfaces which contact with said refrigerant liquid have a lower interfacial tension with said liquid than between the liquid and the liquid engaging surfaces of the evaporator for initiating the formation of refrigerant vapor beneath the surface of the liquid.

6. A refrigerating system comprising an evaporator having a quantity of liquid refrigerant therein, and ebullition means comprising a piece of wood whose surfaces which contact with said refrigerant liquid have a lower interfacial tension with said liquid than between the liquid and the liquid engaging surfaces of the evaporator for initiating the formation of refrigerant vapor beneath the surface of the liquid, and means for maintaining said ebullition means in a fixed position within said evaporator.

7. A refrigerating system comprising a refrigerant evaporating unit having a plurality of tube loops associated therewith, and means in alternate legs of succeeding loops of the evaporator for initiating the formation of vapor bubbles therein comprising a member whose surfaces which contact with said refrigerant liquid have a lower interfacial tension with said liquid than between the liquid and the liquid engaging surfaces of the evaporator.

8. A refrigerating system comprising an evaporator having a quantity of liquid refrigerant therein and ebullition means deposed therein comprising a piece of wood having surfaces which contact with said refrigerant and which have a low interfacial tension with the liquid for initiating the evaporation of the liquid.

9. A refrigerating system comprising an evaporator having a quantity of liquid refrigerant therein and ebullition means of vegetable organic nature submerged in said liquid adjacent the lowermost part of the evaporator, said means having surfaces which contact with said liquid refrigerant and which have a lower interfacial tension with vapor than with the liquid refrigerant for initiating vapor formation adjacent the lowermost part of the evaporator, said means being so constructed and arranged as to allow free passage of the liberated vapor to the vapor space in the evaporator.

10. A refrigerating system comprising an evaporating unit having a quantity of liquid refrigerant confined therein, and means composed principally of a substance of vegetable organic nature submerged in said liquid refrigerant adjacent the lowermost part of the evaporator for initiating the formation of refrigerant vapor below the liquid level therein, said means being so arranged as to allow free passage of liberated vapor to the vapor space in the evaporator.

11. A refrigerating system comprising an evaporating unit having a quantity of liquid refrigerant confined therein, and means submerged in said liquid adjacent the lowermost part of the evaporator for initiating the formation of refrigerant vapor below the liquid level therein, said means comprising a substance of vegetable organic nature having a capillary surface, and said means being so formed and arranged as to allow free passage of liberated vapor to the vapor space in the evaporator.

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