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METHOD OF EVAPORATING LIQUID REFRIGERANT IN A SEMI-FLOODED TYPE EVAPORATOR

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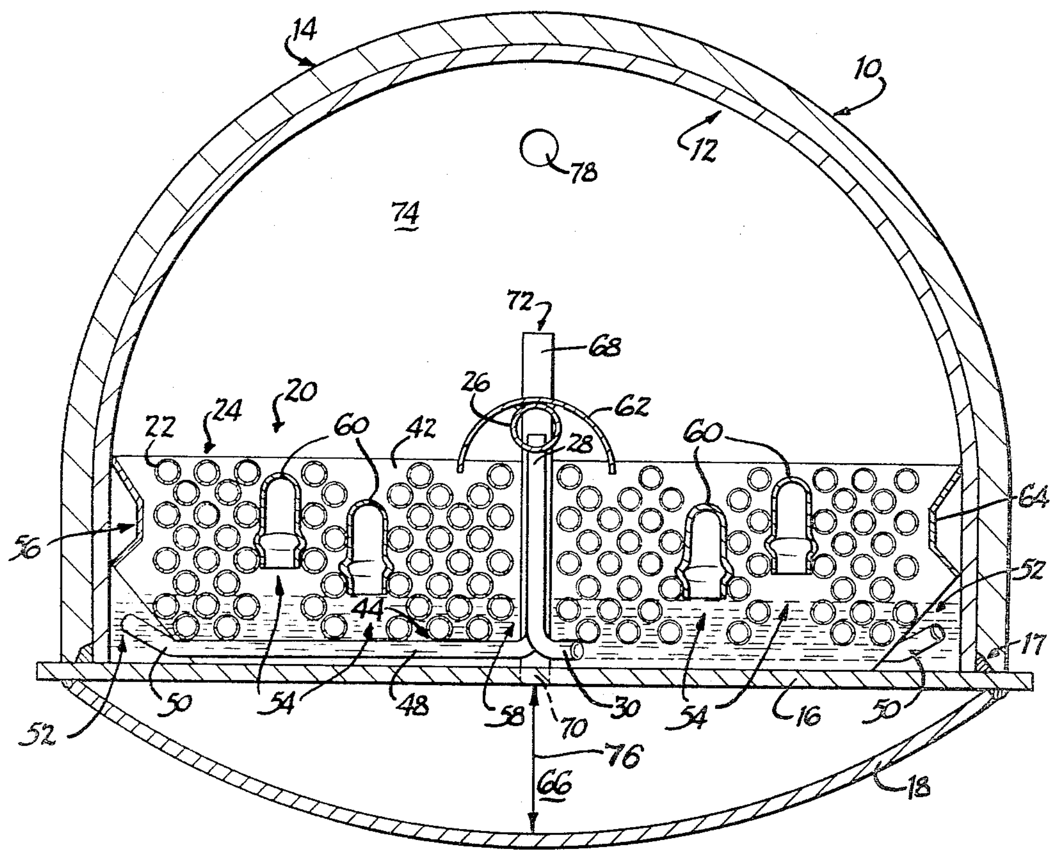

FIG. 1

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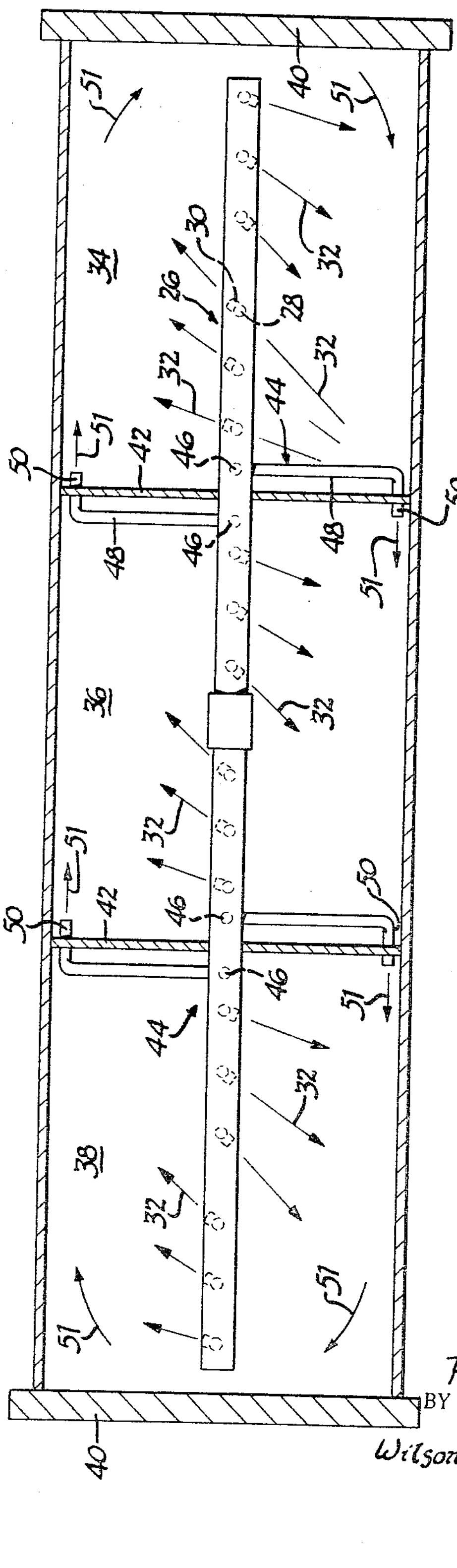

FIG. 2

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METHOD OF EVAPORATING LIQUID REFRIGERANT IN A SEMI-FLOODED TYPE EVAPORATOR

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Original application Oct. 3, 1962, Ser. No. 228,055, now Patent No. 3,240,265, dated Mar. 15, 1966. Divided and this application June 1, 1965, Ser. No. 478,500

4 Claims. (Cl. 62—114)

This invention relates to refrigeration evaporator systems, and more particularly to an improved refrigeration evaporator of the flooded type, and to the method of operation.

This application is a division of my copending application, Serial No. 228,055, filed October 3, 1962, now Patent Number 3,240,265.

In the operation of flooded evaporators in refrigeration systems, it is common practice to submerge only part of the tubes in liquid refrigerant, and allow the boiling action of the refrigerant to splash liquid from a lower level over the upper tubes.

This, theoretically, is a good way to operate. However, as the load reduces, i.e., as the heat exchange tubes operate at a lower temperature level, the boiling action of the liquid refrigerant subsides because of less temperature differential between the liquid refrigerant and the heat exchange tubes. The result is that there is a lesser amount of upper tube wetting by the liquid because of the diminished boiling action. As this happens, the effective heat transfer surface is reduced. As a consequence, the mean difference in temperature between the outgoing water in the tubes and the boiling temperature of the refrigerant in the evaporator is not reduced as the load in reduced (this mean temperature difference being termed the "approach"). If the tube surfaces were more uniformly in operation under all load conditions, the approach would be reduced with a reduction in the load resulting in increased operating efficiency of the system.

Accordingly, an important step forward would be provided in the art by a novel refrigerant evaporator wherein the tubes could be operated at less than fully submerged levels, wherein the boiling action was nevertheless maintained at a uniform rate and thereby utilized to splash liquid uniformly over all of the exposed tubes. A further advance would be provided in the art by a refrigeration evaporator wherein the boiling section of the refrigerant were fully utilized and wherein other improvements of more efficient operation were provided.

An important object of the present invention is to provide a method of evaporating liquid refrigerant in a refrigeration evaporator of the heavy duty industrial semi-flooded type.

A further object is to provide a method of evaporating liquid refrigerant wherein the bubbling action due to flash vaporization of a portion of the entering liquid refrigerant is substantially equally distributed throughout the evaporator to substantially evenly splash liquid over the heat exchange tubes that are exposed above the liquid.

Another object of the invention is to provide a method wherein a thin layer of oil is present on the pool of liquid refrigerant, circulation being provided within the evaporator to maintain the layer of oil evenly over the surface of the pool of refrigerant.

Another object is to provide a method of evaporating liquid refrigerant from a shallow, horizontal pool of uniform depth on which a uniform covering layer of oil is provided for improved heat transfer.

Other objects of this invention will appear in the following description and appended claims, reference being had to the accompanying drawings forming a part of this specification wherein like reference characters designate corresponding parts in the several views.

In the drawings:

FIGURE 1 is a transverse sectional view of a refrigerant evaporator made in accordance with the present invention; and

FIGURE 2 is a longitudinal sectional view showing a schematic arrangement of a liquid refrigerant distribution system in an evaporator made in accordance with the present invention.

Before explaining the present invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and arrangement of parts illustrated in the accompanying drawings, since the invention is capable of other embodiments and of being practiced or carried out in various ways. Also, it is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation.

Briefly, the present invention relates to a novel and improved refrigeration evaporator of the semi-flooded type wherein the bubbling action due to the liquid refrigerant which boils is fully utilized to splash liquid over all of the heat exchange tubes, even when operating with a liquid level substantially below the top of the tube bundle.

The unexpected result is provided by a tube bundle which in transverse cross section has a relatively shallow, even depth, and with vapor diverters strategically located in the bundle to force the rising vapor uniformly through the entire tube bundle for uniform tube wetting; and by a liquid refrigerant delivery system assuring uniform spreading of the entering liquid refrigerant over the bottom of the unit.

Still further, uniform and improved results of operation are provided in accordance with the present invention by utilizing oil in the liquid refrigerant to facilitate wetting of the heat exchange tubes by splashing, even at low liquid levels, by retaining the oil in a uniformly distributed layer over the top of the liquid refrigerant.

As shown in FIGURE 1, an improved refrigeration evaporator in accordance with the present invention is designated by the reference numeral **10**. This unit includes an upper dome-like shell of pressure resistant material such as steel, and designated by the numeral **12**. An outer insulation layer is provided at **14**. A flat transverse wall **16** is provided across the bottom of the upper steel shell **12** to support the tube bundle as will be hereinafter set forth. The shell **12** and wall **16** are joined by welding as at **17**.

Across the bottom of the unit there is provided a concave wall **18**, so configured in order to resist internal pressures of the unit and, as will be evident from the following description, providing a vapor space beneath the wall **16** for insulation, and for purposes of equalizing pressures above and below wall **16**.

By reference to FIGURE 1, it will be noted that the tube bundle is designated broadly by the number **20** and is of generally rectilinear outer configuration. Actually, the tube bundle is rectangular in cross section and the bounding sides, top and bottom, are generally straight lines. It will also be noted that the tubes **22** of the bundle **20** lie in a generally straight line along the bottom, conforming to the flat upper surface of the intermediate or flat transverse wall **16**.

Thus, every vertical column of tubes designated by the reference numeral **24** is essentially of the same height and thus operates with substantially the same submergence to obtain complete tube wetting.

By reference to both figures of the drawings, it will be noted that a distribution main tube designated by the reference numeral **26** extends axially of the unit for conducting liquid and flash gas from the high side float or other valve of a suitable refrigeration system. It should be noted at this point that liquid refrigerant on the condenser side of a float valve is at a higher temperature and higher pressure than refrigerant on the evaporator side of the float valve. As soon as liquid refrigerant passes through the float valve, it is subjected to the temperature and pressure conditions on the evaporator side. The lower temperature and lower pressure on the evaporator side results in a portion of the liquid refrigerant which passes through the float immediately vaporizing. This is termed "flash vaporization." Extending downwardly from the distributor main 26 are a plurality of feeder tubes 28 of vertical disposition and uniformly spaced along the length of the main 26. Nozzles 30 are provided at the bottom end of each of the vertical feeder tubes 28 and are directed horizontally and sized to impart a moderate velocity to the incoming refrigerant and are directed in the fan-like pattern shown by the arrows 32, FIGURE 2, to create a uniform circulation across the bottom of each compartment 34, 36 and 38 defined by the transverse end tube sheets 40 and the transverse tube support sheets 42.

At each support sheet 42, there are provided circulator tubes 44, comprising a down comer 46 and a lateral feed 48 with an upturned end elbow-nozzle 50. The circulator tubes 44 run from the distribution tube 26 downward via the down comer 46, then horizontally via the lateral arm 48 below the tube bundle 20 to the outer edges, then rise and turn via the elbow-nozzle 50 towards the tube support sheets 42, in the manner shown, so as to impart a jet of refrigerant through openings 52 at the lower corners of the tube support sheets 42. These jets are arranged to effect the circulation between compartments in the same direction of rotation, as indicated by arrows 51, and in the same direction as the local circulation within each compartment 34, 36, 38, as designated by the arrows 32.

It should be noted at this point that it is important that openings 52 be high enough and the raised elbow-nozzles 50 be at a proper level to cause the high concentration of surface oil to migrate from one compartment to another in a continuous and uniform pattern, thereby preventing the concentration of oil in any one location and the depletion of oil in any other location. In substance, the total circulation pattern provides a uniform covering of oil over the entire body of liquid refrigerant within the unit.

In order to get most effective tube wetting with minimum refrigerant level, it is important that the boiling action of the incoming refrigerant be confined to the specific tube bundles or vertical tube columns 24, and not be permitted to escape up through the pass rib channels 54, outer edges 56, or center channel 58, see FIGURE 1. The channels 54 are present as a result of partitions required in conventional headers (not shown) provided at each end of the evaporator. To make certain that this does not happen, blocks 60 are inserted between the vertical tube columns 24 at the tops of channels 54. Further, a cap member 62 is provided over the center channel 58. Still further, blocking members 64 are provided along the sides of the tube bundle 20, as indicated in FIGURE 1.

The specific design of the block 60, cap member 62 annd block 64 is not critical. However, the function they perform is highly important, namely to prevent vapor from escaping up through any open channels, and thus, the blocks are inserted near the top of the channels. It will be appreciated that if the open channels were not blocked, they would function much in the manner of a chimney. A low pressure condition would thus result at the bottom of the channels. This low pressure condition would accelerate vaporization of refrigerant directly beneath the channels. The splashing action caused by this vaporization would thus occur directly beneath the channels and result in a large portion of the splashed refrigerant being directed up the channels rather than through the tubes. It is desired to have splashing occur beneath the tubes so that the tubes will be wetted. By preventing the occurrence of low pressure conditions at the bottom of the open channels, vaporization of refrigerant will take place uniformly over the entire pool of refrigerant thus resulting in flashing of liquid refrigerant evenly on the tubes.

In FIGURE 1, there is shown one method of construction for achieving the rectangular tube bundle required for optimum results, wherein the evaporator is in its own individual shell. In this arrangement, the transverse plate 16 is continuous, forming the required flat bottom of the evaporator proper for holding liquid refrigerant at a desired uniform depth. The underlying curved bottom 18 forms the bottom exterior wall of the shell. As previously indicated, this is of concave configuration and therefore resistant to internal pressures.

A vapor space 66 is provided between the concave bottom wall 18 and the flat transverse bundle support wall 16 to provide a dead gas space for purposes of thermal insulation against inward heat transfer from the ambient atmosphere.

It will be noted that a vent tube 68, FIGURE 1, is connected at its lower end into an opening 70 in wall 16 and extends upwardly above the top level of the tube bundle 20. It will be noted that the top 72 of vent tube 68 extends well above the top of tube bundle 20 and thus the vapor space 66 below wall 16 is vented to the upper vapor space 74 above wall 16 and the tube bundle, thereby equalizing pressures on the opposite sides of wall 16 and preventing any lateral load tendency to buckle the same.

Bottom wall 18 thus works on pure tension or compression to maintain the shell shape when portions 12 and 16 are subjected to internal or external pressures. Because the vapor space 66 is filled with refrigerant gas at very low pressure, it acts as an insulator so that no external insulation is required over the bottom of the shell, thus contributing to manufacturing economy and operating efficiency of the unit.

Vapor outlet for the unit is provided at 78.

When it is understood that stagnant gaseous refrigerant, either hot or cold, is a good heat insulator, the economy of the present invention is fully appreciated. Because the vapor space 66 is horizontal and narrow, convection currents are kept to a low level.

Also, by using a fairly wide structure with concave strengthening member 18 beneath a structure is provided which permits the use of a shallow evaporator tube bundle. This tube bundle configuration greatly improves the heat transfer coefficient of the evaporator.

It has been found that a desired height for space 66, as indicated at the point 76, is about one inch per foot of concavity. Thus, for a three foot span, a dimension at the point 76 would be about 1½ to about 3 inches. This assures that convection and eddy currents are kept to a minimum, thus substantially neutralizing heat transfer to the interior of the unit from ambient surroundings.

In accordance with the present invention, use is made of the addition of small quantities of oil to the refrigerant to markedly improve the boiling action, the action continuing to wet all tubes even with liquid refrigerant at a low load level and with the refrigerant at lower levels in the bundle.

As is well known, in the prior art, the strongest boiling action occurs at the entering water, i.e., where the water temperature is highest. This causes the level of refrigerant to drop in this region of an evaporator and thus effects a gradient of surface flow from the other areas of the evaporator to this warmest area. Because the fresh, clean refrigerant from the condenser is being brought in at the bottom and because of the boiling action, the oil is concentrated near the top of the refrigerant. Thus, the surface flow mentioned above carries the oil with it and the oil concentrates at the warmest area of the evaporator and the other areas become essentially oil free. This is obviously undesirable because it negates the effect of the oil in the major part of the evaporator and amplifies the natural difference in boiling action due to difference in water temperature.

The present invention, by utilizing a uniform refrigerant level by the aforedisclosed distribution and circulation system, distributes the liquid refrigerant in such a way that oil distribution is maintained uniform as a layer over the entire body of liquid and the tendency for it to concentrate is therefore counteracted.

Although the foregoing description has related to a unitary refrigerant evaporator for use by itself; that is physically separated from other refrigeration equipment except for connecting lines, it is to be included within the scope of invention to utilize the novel evaporator structure in a unitary shell, as associated with a condenser, also positioned therein. When so operating, the evaporator structure is desirably placed uppermost in the shell structure, with advantage thereby being taken of the gas space 66 for insulation purposes to prevent heat transfer between the two associated units.

The foregoing description has related to the wall 18 as being of concave configuration. However, the broad scope of invention would include a flat wall at 18, given sufficient subjacent support as by tube bundle supports of a subjacent condenser of a unitary shell structure mentioned above.

If desired, the bottom wall 18 may be insulated in some applications where heat transfer must be kept to an absolute nil level.

From the foregoing, it will be evident that the present invention provides a unique and more highly efficient evaporator tube bundle arrangement and liquid refrigerant distribution system than has heretofore being provided in the prior art.

A further advantage of the present invention resides in the fact that greatest utilization of oil for tube wetting and for uniform boiling action and heat transfer efficiency is provided by the novel and uniform refrigerant distribution system of the present invention.

It will be noted that another advantage of the present invention resides not only in improved heat transfer and efficiency of cooling even at low liquid refrigerant levels, but also in the low head room provided by virtue of the horizontal disposition of the device. Thus, low head room and low installation costs are evident from the present invention.

Having thus described my invention, I claim:

1. A method of evaporating liquid refrigerant in a refrigeration evaporator system of the semi-flooded type in which the evaporator includes an elongated hollow shell having therein an axially extending tube bundle partially submerged in a pool of liquid refrigerant and wherein the boiling action of the refrigerant splashes liquid from a lower level over the upper tubes characterized in the steps of forming the liquid refrigerant into at least one horizontally disposed pool of uniform depth, moving the refrigerant from a point of higher pressure than the pressure in the evaporator into said pool in a plurality of streams flowing parallel to the bottom thereof and directed in a horizontal fan pattern which produces a swirling motion in the pool about a horizontal circle and uniformly distributes the incoming refrigerant throughout the pool, thereby resulting in flash vaporization of a portion of the incoming refrigerant due to the pressure differential whereby, as a result of the uniform distribution of the incoming refrigerant, the flash vaporization occurs uniformly throughout the pool, and heat exchanging the liquid refrigerant with warmer fluid passing through the tube bundle.

2. A method according to claim 1 characterized in that the streams of liquid refrigerant originate along the longitudinal axis of the pool and are directed outwardly therefrom towards the outer edges of the pool.

3. A method of evaporating liquid refrigerant in a refrigeration evaporator system of the semi-flooded type in which the evaporator includes an elongated hollow shell having therein an axially extending tube bundle partially submerged in a pool of liquid refrigerant and wherein the boiling action of the refrigerant splashes liquid from a lower level over the upper tubes, characterized in the steps of forming the liquid refrigerant into at least one horizontally disposed pool of uniform depth, providing a layer of oil overlying the pool of refrigerant, moving streams of liquid refrigerant into said pool, directing said streams of liquid refrigerant parallel to the bottom of said pool in a horizontal fan pattern which uniformly distributes the incoming refrigerant throughout the pool and causes continuous horizontal swirling movement of the entire pool of refrigerant to result in continuous migration of the oil to maintain the oil as a uniform layer, moving the refrigerant from a point of higher pressure than the pressure in the evaporator to result in flash vaporization of a portion of the incoming refrigerant due to the pressure differential whereby, as the result of the uniform distribution of the incoming refrigerant, the flash vaporization occurs uniformly throughout the pool, and heat exchanging the liquid refrigerant with warmer fluid passing through the tube bundle.

4. The method according to claim 3, characterized in the step of forming the liquid refrigerant into a plurality of horizontally disposed pools abutted at their ends and open to one another at spaced points along their ends, aiming the streams of liquid refrigerant to cause continuous circulatory movement of each individual pool of liquid refrigerant and continuous circulatory movement between adjacent pools of liquid refrigerant to maintain the oil as a uniform layer.

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LLOYD L. KING, *Primary Examiner.*