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3,264,836

REFRIGERATION SYSTEM AND METHOD

Filed March 4, 1964

2 Sheets-Sheet 1

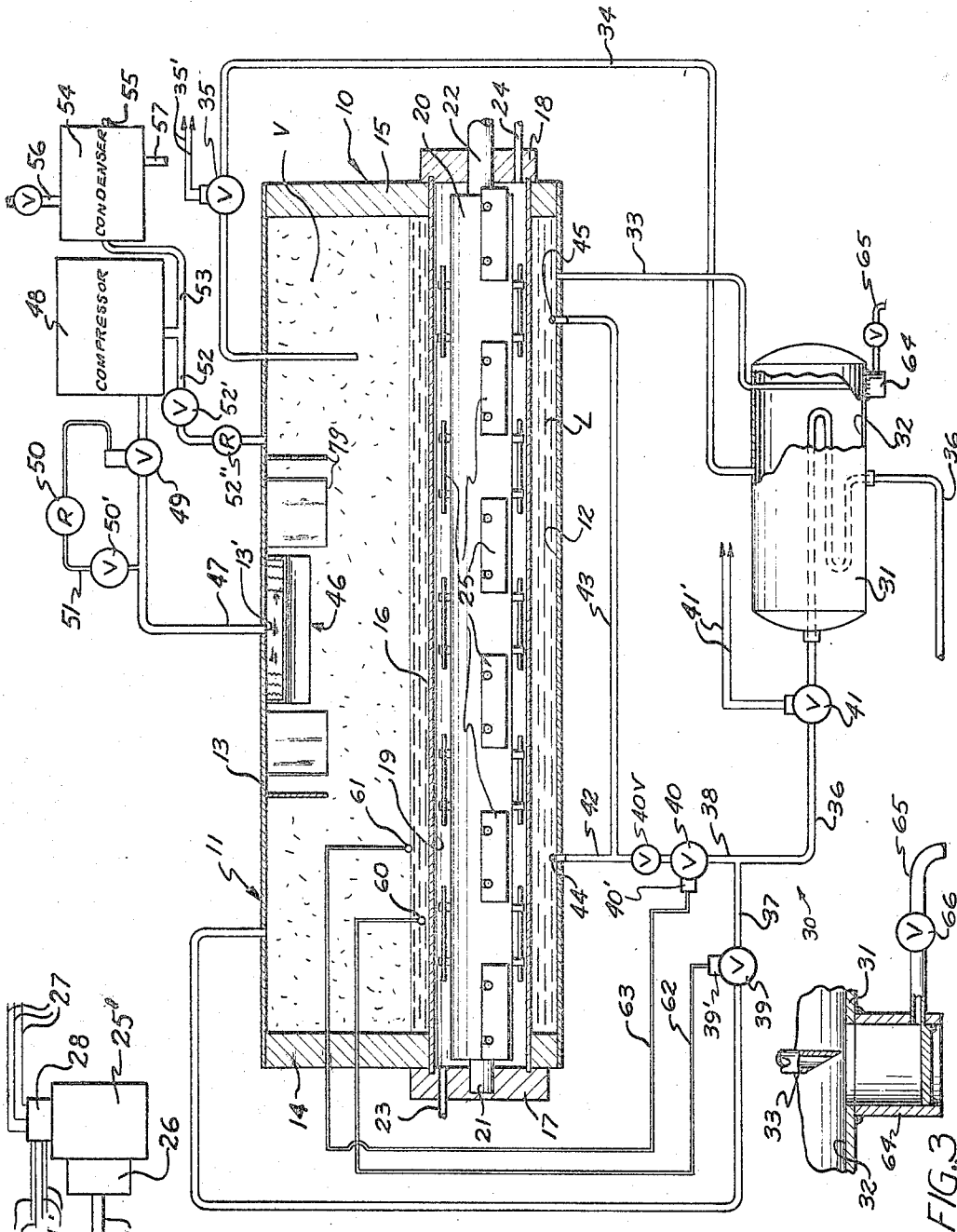


FIG. 2

FIG. 1

FIG. 3

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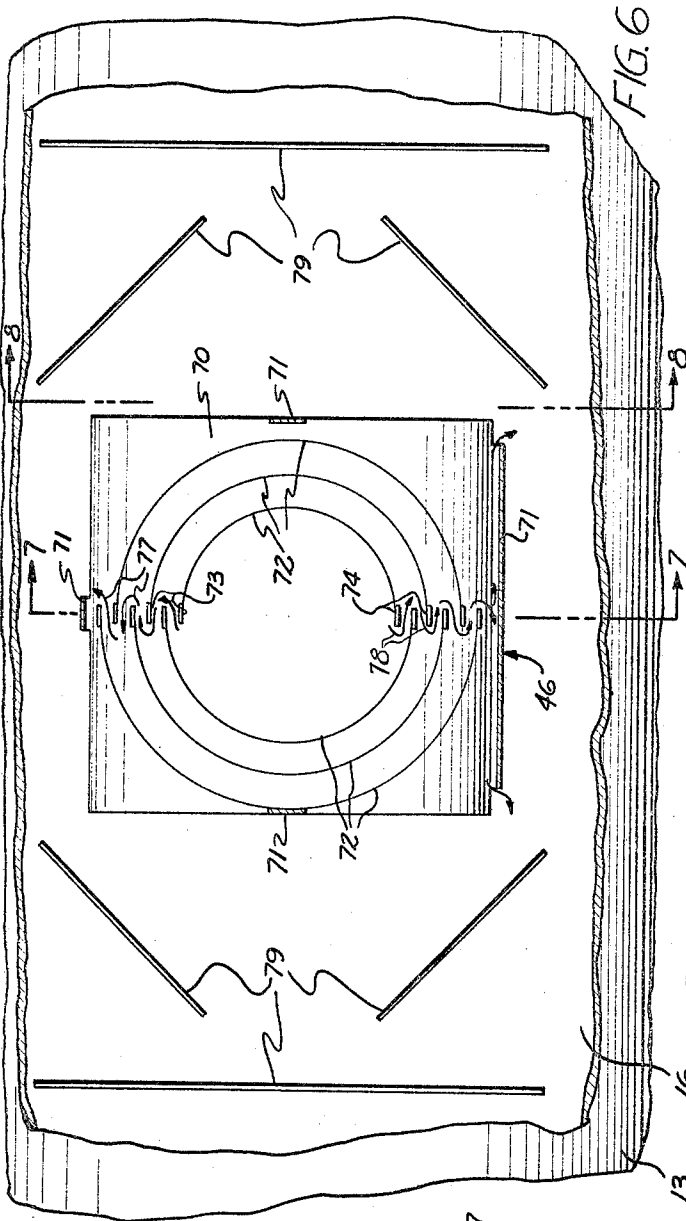


FIG. 6

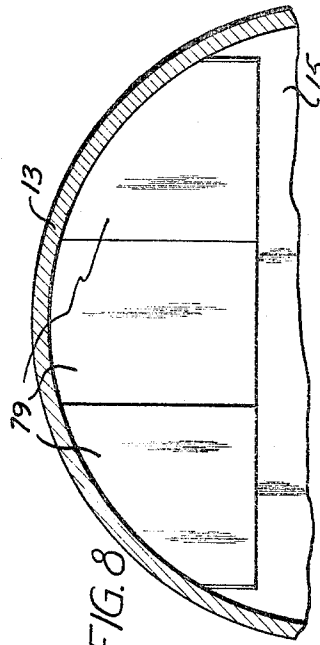


FIG. 8

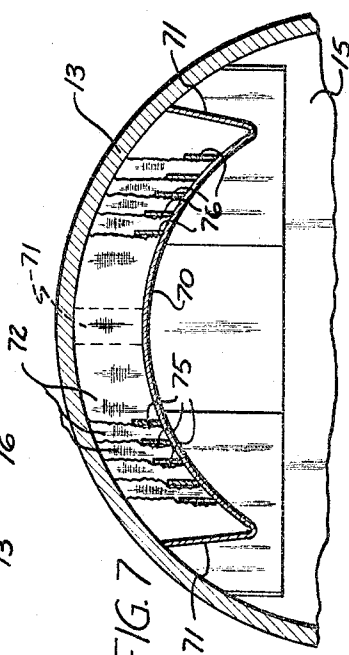


FIG. 7

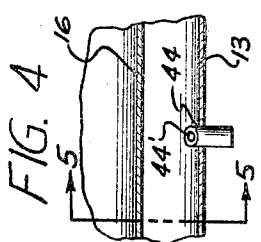


FIG. 4

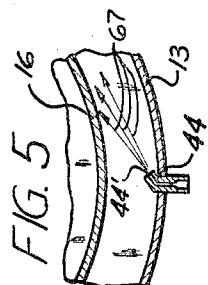


FIG. 5

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## REFRIGERATION SYSTEM AND METHOD

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11 Claims. (Cl. 62—115)

This invention relates to a refrigeration system and method in which a vaporizable liquid refrigerant and its vapor are used.

It is a feature of the invention to provide a reliable and economical refrigeration system and method by which materials can be refrigerated by using a vaporizable liquid refrigerant and its vapor, in which a refrigerant chamber can be emptied of the liquid refrigerant into a vessel disposed at a lower elevation and the liquid refrigerant can be returned to the refrigerant chamber by effecting vaporization of some of the liquid refrigerant, with the system having a relatively small vertical overall dimension, and the system and method being particularly advantageous when the refrigerant is ammonia because oil which may be present along with the ammonia gravitates into the vessel and hence is not capable of impairing the heat transfer efficiency of the heat exchanger.

It is another feature of the invention to provide a method by which a vaporizable refrigerant is discharged into a refrigerant chamber, with the refrigerant being discharged under pressure and in a direction to skim across a portion of the periphery of the heat transfer member and to effect movement of the refrigerant in the refrigerant chamber around the heat transfer member.

In the drawings:

FIGURE 1 is a schematic view showing a refrigeration system for a heat exchanger;

FIGURE 2 is a schematic view showing a drive mechanism and an overload responsive mechanism for the heat exchanger;

FIGURE 3 is a fragmentary sectional view showing the construction by which a vessel shown in FIGURE 1 can be drained;

FIGURE 4 is a fragmentary view, mainly in section, showing one of the nozzles for discharging liquid refrigerant into a refrigerant chamber of the heat exchanger;

FIGURE 5 is a sectional view taken along line 5—5 of FIGURE 4;

FIGURE 6 is a top plan view showing a separator for the heat exchanger;

FIGURE 7 is a sectional view taken along line 7—7 of FIGURE 6; and

FIGURE 8 is a sectional view taken along line 8—8 of FIGURE 6.

Referring now to FIGURE 1 of the drawings, there is shown a heat exchanger generally indicated at 10. The heat exchanger 10 has a shell generally indicated at 11 which includes a horizontal circular tube 13 and end plates 14 and 15. The shell 11 defines a chamber 12 adapted to contain a liquid refrigerant L and its vapor V. Disposed at the lower portion of the refrigerant chamber 12 is a heat transfer member 16 which is shown to take the form of an elongated horizontal circular tube. End plates 17 and 18 suitably secured to the end plates 14 and 15 close off the end of the heat transfer member 16. The heat transfer member 16 defines a material chamber 19 for material to be refrigerated. A shaft 20 is mounted by stub end portions 21 and 22 in end plates 17 and 18. Conduits 23 and 24 are employed to pass flowable material to be refrigerated into and out of the material chamber 19. The shaft 20 carries a plurality of scraper blades 25 which scrape the inner surface of the heat transfer

member 16, to cause mixing among other things, as is conventional.

As shown in FIGURE 2, an electric motor 25' drives the stub end portion 22 through a speed reducer 26. Electrical energy is supplied to the motor 25' by leads 27 through a conventional overload responsive mechanism 28 which senses any overload of motor 25'. A typical overload is caused when the material in the material chamber 19 becomes too viscous.

A refrigeration system in accordance with the invention is generally indicated at 30. The refrigeration system 30 includes the refrigerant chamber 12 of the heat exchanger 10. A vessel 31 defines a chamber 32. A sump 64 forms the lowermost region of the vessel 31, and any relatively heavy contaminant such as oil which separates out of the refrigerant can be drained out through a conduit 65 which contains a valve 66. A conduit 33 is shown to provide communication between the lowermost region of the refrigerant chamber 12 and the lower region of the chamber 32 of the vessel 31. The conduit 33 is shown to be in constant communication with the chamber 12 and the vessel 31. A conduit 34 can provide communication between the refrigerant chamber 12 and the vessel 31 when a solenoid operated valve 35, disposed in the conduit 34, is open.

At least the lower region of the vessel 31 is disposed at a sufficiently lower elevation than the lowermost region of the refrigerant chamber 12 so that all the liquid refrigerant in the refrigerant chamber 12 can gravitate through the conduit 33 into the vessel 31 when the valve 35 is opened, thereby equalizing the pressure in chambers 12 and 32. In order that the liquid refrigerant in the vessel 31 can be vaporized to force liquid refrigerant to pass from the vessel 31, through the conduit 33 and into the refrigerant chamber 12 when the valve 35 is closed, some of the liquid refrigerant in the vessel 31 is vaporized by heating the liquid refrigerant. One manner of heating the liquid refrigerant in the vessel 31 is to pass a conduit 36 into heat exchange relationship with the vaporizable liquid refrigerant in the vessel 31. During normal operation of the system, the pressure is always sufficiently higher in chamber 32 than in the chamber 12 to offset the head of liquid refrigerant in line 33, thereby preventing the liquid refrigerant in chamber 12 from dumping into the chamber 32. Should the pressure in the chamber 32 be insufficient to hold the liquid L in the chamber 12, a small quantity of the liquid L will gravitate through the conduit 33 into the chamber 32 even though the valve 35 in the conduit 34 is closed. The liquid which enters the chamber 32 through the conduit 33 will be vaporized by heat from ambient air which heats the vessel 31 and by heat from the relatively warm liquid refrigerant passing through the conduit 36 in heat exchange relationship with the refrigerant in the chamber 32, thereby increasing the pressure in the chamber 32 to prevent additional liquid gravitation through the conduit 33. Such gravitation and vaporization of liquid refrigerant and concomitant pressure rise in the chamber 32 occurs whenever the pressure in the chamber 32 is insufficient. The conduit 36 is shown to lead from a source of vaporizable liquid refrigerant supply, through the vessel 31 and to the refrigerant chamber 12.

The conduit 36 branches into branch conduits 37 and 38 which contain valves 39 and 40 having actuators 39' and 40', respectively. A solenoid operated valve 41 is disposed in the conduit 36 upstream of the branch conduits 37 and 38. The branch conduit 37 is shown to lead to the top of the refrigerant chamber 12. The branch conduit 38 is shown to be connected to conduits 42 and 43. The conduits 42 and 43 are connected to nozzles 44 and 45, respectively. A needle valve 40v is disposed in the branch con-

duit 38 downstream of the valve 40 and upstream of the conduits 42 and 43.

A separator generally indicated at 46 is employed to separate entrained liquid from the refrigerant vapor V which is passed from a discharge opening 13' in the tube 13 through a conduit 47 to a compressor 48. A valve 49 in the conduit 47 is operated whenever the pressure in the conduit 47 upstream of the valve 49 exceeds a preselected value, in response to a signal from a pilot regulator 50. The pressure at which the pilot regulator 50 opens the valve 49 determines the temperature of the refrigerant in the chamber 12. A conduit 51 connects the conduit 47 upstream of the valve 49 to the regulator 50 and connects the regulator 50 to the valve 49.

The compressor 48 discharges hot compressed refrigerant vapors into a conduit 53 and also in a conduit 52 containing a valve 52' and a pressure regulator 52". The conduit 52 leads into the refrigerant chamber 12, while the conduit 53 leads to a condenser 54 where the refrigerant vapor is condensed and the condensed liquid is discharged through a conduit 55. The conduit 55 can be connected to a receiver (not shown) which in turn can be connected to the conduit 36 as is conventional, or the conduit 55 can be connected directly to the conduit 36. A valved conduit 56 and a conduit 57 enable a coolant to be passed into the condenser 54, into heat exchange relationship with the refrigerant vapors, and out again.

A control for sensing a low liquid level in the refrigerant chamber 12 is generally indicated at 60, while a control for sensing a high liquid level in the refrigerant chamber 12 is generally indicated at 61. The controls 60 and 61 can be of any suitable type, for example the type sold by the Sporlan Valve Company of St. Louis, Missouri and disclosed in their bulletin 60-15. Assuming the refrigerant chamber 12 has no liquid refrigerant in it, both valves 39 and 40 will be open because the controls 60 and 61 sense no liquid. When a low liquid level, which is slightly above the heat transfer member 16, is sensed the valve 39 is closed in response to a signal received through a tube 62 of the control 60. When a high liquid level, which is disposed above the low liquid level, is sensed the valve 40 is closed in response to a signal received through a tube 63 of the control 61. During operation, liquid refrigerant L is continuously vaporizing and the liquid level drops until the control 61 actuates the valve 40 into the open position, permitting liquid refrigerant to enter the chamber 12 through nozzles 44 and 45 until the control 61 again senses liquid, whereupon the valve 40 is actuated into the closed position. Such opening and closing of the valve 40 is repeated each time the liquid level falls and rises as described above. The needle valve 40v controls the quantity of liquid refrigerant passing through the nozzles 44 and 45. Should the needle valve 40v be set so that insufficient refrigerant passes through the nozzles 44 and 45 into the chamber 12 and the refrigerant liquid level falls below the low liquid level, the control 60 will open the valve 39 so that liquid refrigerant can pass into the chamber 12 through the conduit 37 as well as through the conduits 42 and 43.

As the nozzles 44 and 45 are identical in construction and arrangement, only the nozzle 44 is shown in detail in FIGURES 4 and 5. The nozzle 44 has a restricted discharge opening 44' for discharging the vaporizable liquid refrigerant into the chamber 12 and toward a portion of the periphery of the heat transfer member 16. As the refrigerant is discharged, some of it vaporizes due to the pressure drop upon leaving the nozzle 44. The nozzle 44 is so directed that the liquid refrigerant is discharged into the refrigerant chamber 12 and skims across a portion of the periphery of the heat transfer member 16, thereby causing the heat transfer member 16 to be cooled by the liquid refrigerant and its vapor and additionally imparting motion to the liquid refrigerant in the refrigerant

chamber 12 so that it passes around the heat transfer member 16. In particular, the nozzle 44 is so directed that the liquid refrigerant is discharged tangentially to the periphery of the heat transfer member 16 and in a transverse plane as indicated by arrows 67. So long as the nozzles 44 and 45 are discharging liquid refrigerant the liquid refrigerant is caused to pass circumferentially around the heat transfer member 16 which is disposed below the level of the refrigerant.

The separator 46 shown in FIGURES 1, 6, 7 and 8 is in the upper region of the chamber 12. The separator 46 has a sloped plate 70 which, more specifically, is curved so as to be concentric with the inner surface of the tube 13 of the shell 11. The sides of the plate 70 have upturned members 71 which are secured to the inner surface of the tube 13 for example by welding. Screen elements 72 extend from the upper surface of the plate 70 to the inner surface of the tube 13 of the shell 11. The screen elements 72 are generally semicircular and are disposed along concentric paths. Opposed ends 73 and 74 of the screen elements 72 are secured for example by welding to upstanding projections 75 and 76 which are disposed along the sloped plate 70. The projections 75 and 76 are secured to the upper surface of the plate 70 for example by welding. The opposed ends 73 and 74, which are disposed at the place to which the once entrained liquid, separated from the vapor V, gravitates, are overlapped and spaced apart from each other. The liquid can thus take the path represented by the arrows 77 and 78. Liquid can also flow down the sloped plate 70 from the outermost screen elements 72. The screen elements 72 have a mesh size which is sufficiently small so that the liquid will be separated from the vapor V which is to pass into the conduit 47. The liquid can flow off the plate 70 and gravitate onto the surface of the liquid refrigerant L in the chamber 12. Baffles 79 are disposed on both sides of the separator 46 between the places where the conduits 37 and 47 communicate with the refrigerant chamber 12.

To operate the system, assuming the valve 35 is closed and the valve 41 is open, a vaporizable liquid refrigerant such as ammonia is passing under pressure through the conduit 36, into branch conduits 37 and 38, and through conduits 42 and 43 and their nozzles 44 and 45, into the refrigerant chamber 12. The controls 60 and 61 operate to open and close the valves 39 and 40, respectively, as explained above. The motor 25 is operating and the flowable material is passing through the material chamber 19. While the valve 40 is open, vaporizable liquid refrigerant will pass under pressure through the nozzles 44 and 45 to cause both efficient heat transfer from the heat transfer member 16 and passage of the liquid refrigerant L around the heat transfer member 16.

When the pilot regulator 50 senses an excess in pressure in the conduit 47, it opens valve 49 so that the vapor passing through the conduit 47 can be passed to the compressor, and the compressed vapor passed to the condenser 54.

Any relatively heavy, immiscible contaminant such as oil which is in the refrigerant chamber 12 along with the ammonia will gravitate through the conduit 33 and into the vessel 31 since the conduit 33 is in constant communication with the lowermost region of the refrigerant chamber 12 and the vessel 31. Oil typically finds its way into the refrigerant from various mechanisms such as the compressor 48. A small amount of ammonia will also gravitate into the vessel 31. The contaminant will gravitate into and remain in the lowermost region of the vessel 31 such as the sump 64 until it is drained out through the conduit 65 by opening the valve 66, as required.

Should the motor 25 become overloaded, the overload responsive mechanism 28 will cause the opening of the solenoid operated valve 35 so as to establish vent communication between the refrigerant chamber 12 and the chamber 32 of the vessel 31, thus equalizing the pressure

in the refrigerant chamber 12 and the vessel 31. The overload responsive mechanism 28 will also close the solenoid operated valve 41. The overload responsive mechanism 28 is connected to solenoid operated valves 35 and 41 by leads 35' and 41' so that when an overload of the motor 25 is sensed, the valve 35 is automatically opened and the valve 41 is automatically closed. Such pressure equalization will permit the liquid refrigerant to gravitate from the refrigerant chamber 12, through the conduit 33 and into the vessel 31. When the liquid refrigerant L has passed out of the refrigerant chamber 12 into the vessel 31, the valve 52' is manually opened and the valve 50' is manually closed, thereby preventing the regulator 50 from opening the valve 49, so that hot vapors are passed from the compressor 48 into the refrigerant chamber. These hot vapors condense in the chamber 12, and thus release latent heat, rendering the too viscous materials in the chamber 19 less viscous and thereby obviating the overload quickly. The pressure regulator 52' prevents vapors from passing into the chamber 12 when the pressure in the chamber 12 exceeds a pre-selected value.

When it is desired to again pass refrigerant into the chamber 12, the valve 35 is first closed to disestablish the vent communication. Vaporization of some of the liquid refrigerant in the vessel 31 will cause a build up of pressure so as to force liquid refrigerant to ascend through the conduit 33 and into the refrigerant chamber 12. Since the conduit 33 terminates in the lower region of the chamber 32 but short of the lowermost region of the chamber 32 of the vessel 31, the contaminant is prevented from ascending through the conduit 33. Such vaporization is assisted by the relatively warm refrigerant which is in the conduit 36 in heat relationship with the refrigerant in the vessel 31. The valves 35 and 41 can also be opened and closed by operating manual switches (not shown).

Other embodiments and modifications of this invention will suggest themselves to those skilled in the art, and all such of these as come within the spirit of the invention are included within its scope as best defined by the appended claims.

We claim:

1. In a refrigeration system: a heat exchanger including a chamber for liquid refrigerant and a chamber for materials to be refrigerated, a vessel, a first conduit in constant communication with a lowermost region of said refrigerant chamber and a lower region of said vessel, a second conduit communicating with said refrigerant chamber and said vessel, a valve in said second conduit, at least the lower region of said vessel being disposed at a sufficiently lower elevation than said refrigerant chamber to permit liquid refrigerant in the refrigerant chamber to gravitate through said first conduit into said vessel when said valve is opened, and means for effecting vaporization of some of the refrigerant in said vessel to force liquid refrigerant to return through the first conduit to said refrigerant chamber due to increased pressure in said vessel when said valve is closed.

2. In a refrigeration system: a heat exchanger including a chamber for liquid refrigerant and a chamber for materials to be refrigerated, a vessel, a first conduit in constant communication with a lowermost region of said refrigerant chamber and a lower region of said vessel, means communicating with the lowermost region and said vessel for enabling said vessel to be drained, a second conduit communicating with said refrigerant chamber and said vessel, a valve in second conduit, at least the lower region of said vessel being disposed at a sufficiently lower elevation than said refrigerant chamber to permit liquid refrigerant in the refrigerant chamber to gravitate through said first conduit into said vessel when said valve is opened, and means for effecting vaporization of some of the refrigerant in said vessel to force liquid refrigerant to return through the first conduit to said refrigerant

chamber due to increased pressure in said vessel when said valve is closed.

3. In a refrigeration system: a heat exchanger including a chamber for liquid refrigerant and a chamber for material to be refrigerated, a vessel, a first conduit communicating with a lowermost region of said refrigerant chamber and a lower region of said vessel, a second conduit communicating with said refrigerant chamber and said vessel, a valve in said second conduit, at least the lower region of said vessel being disposed at a sufficiently lower elevation than said refrigerant chamber to permit liquid refrigerant in the refrigerant chamber to gravitate through said first conduit into said vessel when said valve is opened, and a third conduit leading from a source of refrigerant to said refrigerant chamber, said third conduit being in heat exchange relationship with the liquid in said vessel to force liquid refrigerant to return from said vessel through said first conduit to said refrigerant chamber due to increased pressure in said vessel when said valve is closed.

4. In a refrigeration system: a heat exchanger including a chamber for liquid refrigerant and a chamber for material to be refrigerated, said heat exchanger having means disposed in said material chamber for mixing the material, means for driving said mixing means, a vessel, a first conduit in constant communication with a lowermost region of said refrigerant chamber and a lower region of said vessel, a second conduit communicating with said refrigerant chamber and said vessel, a valve in said second conduit, at least the lower region of said vessel being disposed at a sufficiently lower elevation than said refrigerant chamber to permit liquid refrigerant in the refrigerant chamber to gravitate through said first conduit into said vessel when said valve is opened, means for effecting vaporization of refrigerant in said vessel to force liquid refrigerant to return from the vessel through the first conduit to said refrigerant chamber due to increased pressure in said vessel when said valve is closed, and means responsive to the overloading of said driving means for opening said valve.

5. In a refrigeration system: a heat exchanger including a chamber for refrigerant and a chamber for material to be refrigerated, said heat exchanger having means in said material chamber for mixing the material, means for driving said mixing means, a vessel, a first conduit communicating with the lowermost region of said refrigerant chamber and the lower region of said vessel, a second conduit communicating with said refrigerant chamber and said vessel, a first valve in said second conduit, at least the lower region of said vessel being disposed at a sufficiently low elevation to permit a liquid refrigerant in the refrigerant chamber to gravitate through said first conduit into said vessel when said first valve is opened, a third conduit for supplying liquid refrigerant to said refrigerant chamber, a second valve in said third conduit, means for effecting vaporization of refrigerant in said vessel to force refrigerant to return through said first conduit to said refrigerant chamber when said first valve is closed, and means responsive to the overloading of said driving means for opening said first valve and closing said second valve.

6. In a refrigeration system: a heat exchanger including a chamber for a refrigerant and a chamber for material to be refrigerated, a vessel, a first conduit communicating with a lowermost region of said refrigerant chamber and a lower region of said vessel, a second conduit communicating with said refrigerant chamber and said vessel, a first valve in said second conduit, at least the lower region of said vessel being disposed at a sufficiently lower elevation than said refrigerant chamber to permit liquid refrigerant in the refrigerant chamber to gravitate through said first conduit into said vessel when said first valve is opened, means for effecting vaporization of refrigerant in said vessel to force refrigerant from said vessel through

said first conduit and into said refrigerant chamber, conduit means for supplying liquid refrigerant to the refrigerant chamber including a pair of branch conduits, a valve in each of said branch conduits, means for sensing a low liquid refrigerant level in said refrigerant chamber, means for sensing a high liquid refrigerant level in said refrigerant chamber, means responsive to said low level sensing means for maintaining said valve in one of said branch conduits open until the low liquid level is attained, and means responsive to high level sensing means for maintaining said valve in the other of said branch conduits open until the high liquid level is attained.

7. In a refrigeration system: a heat exchanger including a heat transfer member defining a chamber for material to be refrigerated and including a chamber for a liquid refrigerant encircling heat transfer member, and means for maintaining the liquid refrigerant level in the refrigerant chamber above said heat transfer member including at least one restricted nozzle disposed below the refrigerant level for discharging liquid refrigerant into the refrigerant chamber, said nozzle being directed to discharge the refrigerant liquid generally tangentially toward the heat transfer member so that the liquid refrigerant in the refrigerant chamber is caused to pass around the periphery of said heat transfer member.

8. In a refrigeration system: a heat exchanger including a heat transfer member defining a chamber for material to be refrigerated and a shell around said heat transfer member defining a chamber for a vaporizable liquid refrigerant and its vapor, a separator in the upper region of said chamber for removing entrained liquid refrigerant from the vapor which is being withdrawn from said chamber, said separator including a plate secured to said shell, at least one screen element extending from said plate into contact with the inner surface of said vessel, said screen having a sufficiently small mesh size to remove excess liquid from the vapor, means for securing said screen element to said plate, said plate being constructed and arranged so that liquid refrigerant which has been removed is capable of flowing off said plate, and a discharge opening in said shell through which vapor can pass from said separator.

9. In a refrigeration system: a heat exchanger including a heat transfer member defining a chamber for material to be refrigerated and a shell around said heat transfer member defining a chamber for a liquid refrigerant and its vapor, a separator in the upper region of said chamber for removing entrained liquid refrigerant from the vapor which is to be withdrawn from said refrigerant chamber, a discharge opening in said shell through which vapor can pass from said separator, said separator including a

sloped plate secured to said shell, and screen elements extending from said sloped plate to the inner surface of said shell and having opposed ends which are spaced apart from each other at the place along the sloped plate to which the removed liquid refrigerant gravitates, said screen elements having a sufficiently small mesh size to remove excess liquid refrigerant from the vapor.

10. Method of refrigeration, comprising the steps of: providing a chamber for refrigerant around a heat transfer member, providing vaporizable liquid refrigerant in the refrigerant chamber to a level above the heat transfer member, and directing vaporizable liquid refrigerant under pressure into the refrigerant liquid in the refrigerant chamber and toward the periphery of the heat transfer member, the discharged refrigerant partly vaporizing upon contact with the heat exchange member so that vapor and refrigerant liquid skim across a portion of the periphery of the heat transfer member and effect movement of the refrigerant in the refrigerant chamber around the heat transfer member.

11. Method of refrigeration, comprising the steps of: providing constant communication between a refrigerant chamber at one elevation and a vessel at a lower elevation, providing a vaporizable liquid refrigerant in the refrigerant chamber, any contaminant in the refrigerant chamber which is relatively heavy and immiscible with the refrigerant being free to gravitate into the vessel, establishing vent communication between the refrigerant chamber and the vessel when it is desired to transfer the refrigerant into the vessel, and vaporizing some of the refrigerant in the vessel to increase the pressure to thus force liquid refrigerant to ascend into the refrigerant chamber after disestablishing the vent communication.

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