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REFRIGERATION METHOD AND APPARATUS FOR LUBRICANT HANDLING

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2 Sheets-Sheet 1

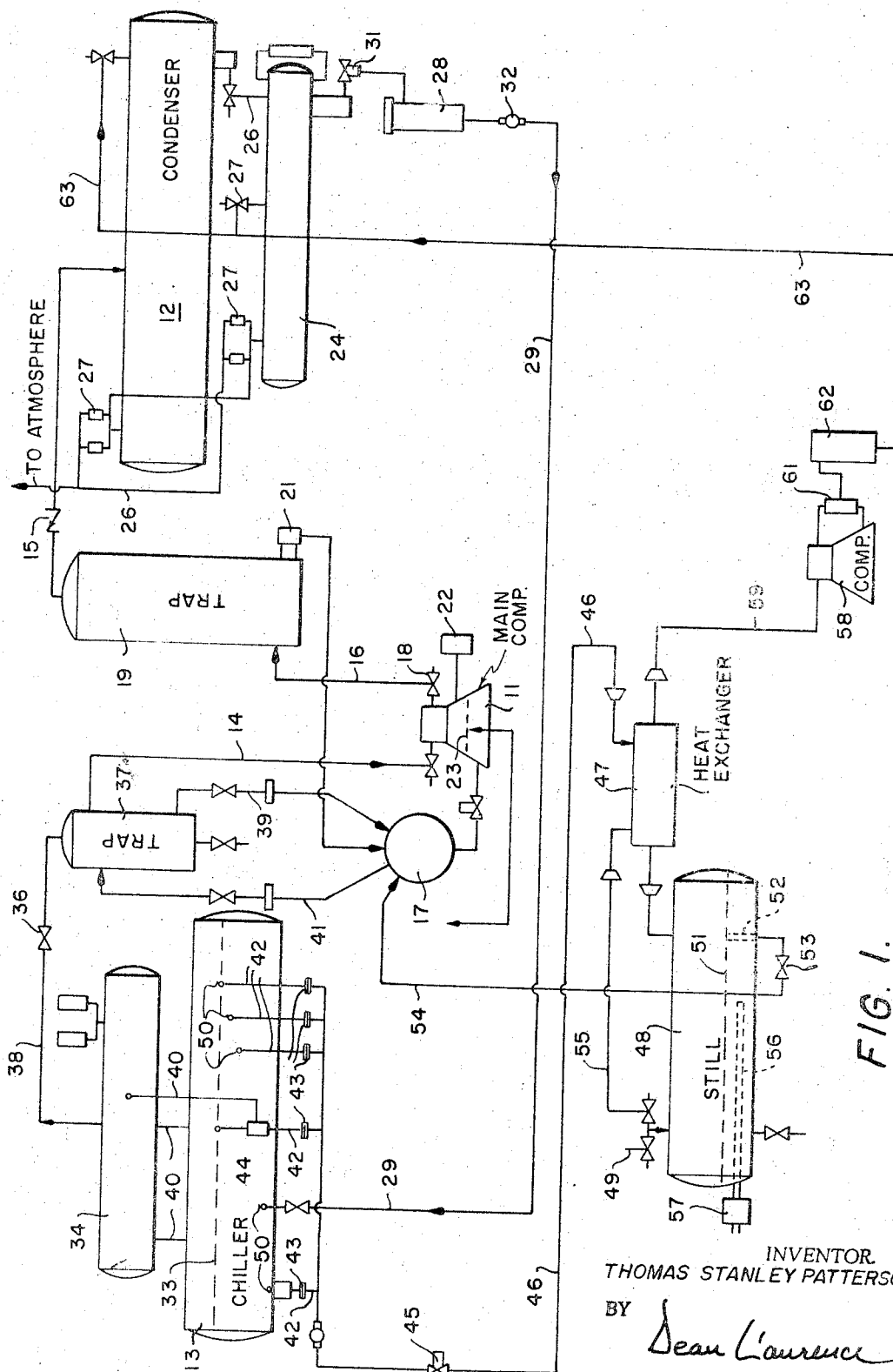


FIG. 1.

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FIG. 2.

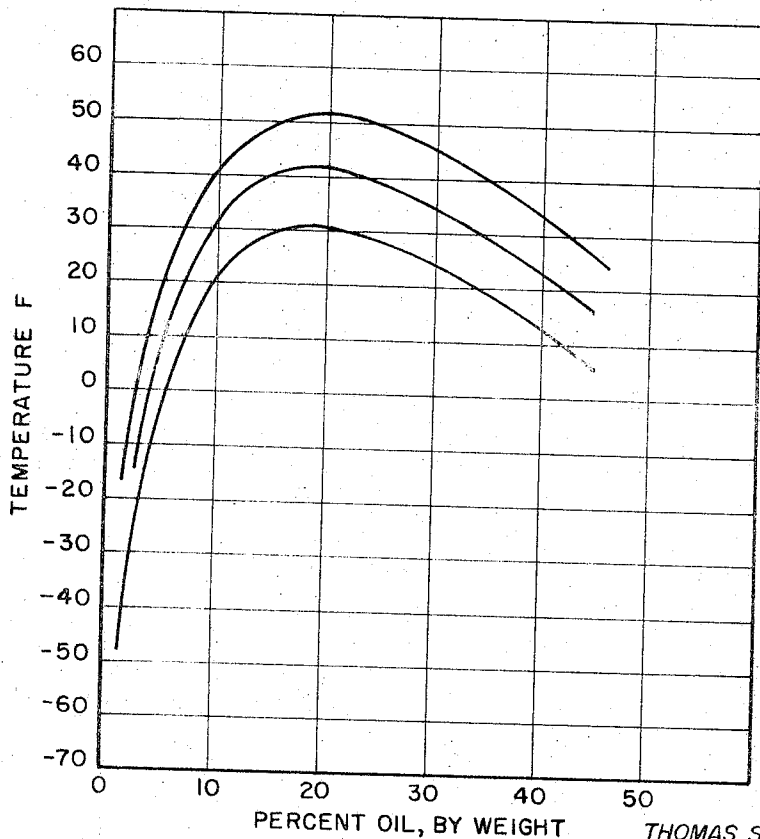
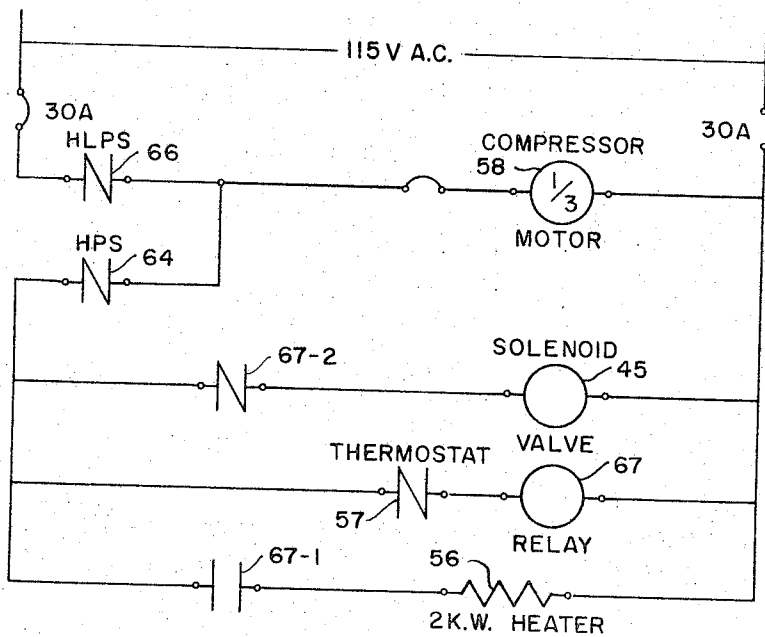


FIG. 3.

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REFRIGERATION METHOD AND APPARATUS FOR LUBRICANT HANDLING

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This invention relates to refrigeration method and apparatus and more particularly to the method of and apparatus for recovering lubricant from the refrigerant-lubricant mixture in a compressor, condenser, evaporator circuit type refrigeration system independently of and without effecting the continuous operation of the refrigeration system.

It is well known that refrigerants are highly miscible and soluble in practically all lubricants used in conventional compressor, condenser, evaporator circuit type refrigeration systems. In spite of all efforts, lubricant is carried through and from known compressors in the form of mist, vapor and droplets and mixes with the liquid refrigerant in the condenser. Over a period of time the lubricant build up in the system reaches a point of saturation depending upon the temperature and pressure and in the evaporator the lubricant comes out of solution forming separate liquid layers. At low temperatures the lubricant in the evaporator becomes so viscous that the stream of gaseous refrigerant created by the compressor suction line cannot return the lubricant back to the compressor. Consequently lubricant builds up in the evaporator reducing heat transfer through the evaporator walls, interfering with the flow of refrigerant, and thus greatly effecting the efficiency of the system.

The only place for lubricant in a refrigeration system is in the compressor and numerous attempts have been made to separate or purge lubricant from the system and return it to the compressor. These have included filters, traps and fractionating stills all of which are a part of and consequently effect the operation of the refrigeration system itself. That is, all known lubricant purging or separation methods and devices depend upon the operation of the compressor of the refrigeration system.

Because of the separation of lubricant from refrigerant in the evaporator, particularly in large, low temperature refrigeration systems, it is a conventional practice to maintain the liquid mixture in the evaporator in a high state of turbulence in an attempt to prevent the coating of the evaporator walls with lubricant and thus reducing the loss of heat transfer through the evaporator walls. However in these systems lubricant continues to build up in the refrigerant with operation and reduces the overall efficiency until it is necessary to shut down. Fractionating stills have been employed to separate the lubricant from the refrigerant-lubricant mixture, however these devices require additional heat and all are dependent upon the continuous operation of the compressor. Further where the refrigerant-lubricant mixture to be distilled is taken from the evaporator it is not selectively removed from the evaporator.

Accordingly an object of this invention is to provide refrigeration method and apparatus for separating lubricant from a refrigerant-lubricant mixture independently of the operation of the refrigeration system.

Another object of this invention is to provide method and apparatus for continuously regenerating a determined volume of a refrigerant-lubricant mixture by separating the lubricant therefrom and returning the lubricant to the compressor while returning substantially pure refrigerant to the condenser.

Another object of this invention is to provide method and apparatus for regenerating a refrigerant-lubricant

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mixture by separating the lubricant from the refrigerant wherein the mixture to be regenerated is selectively removed from the evaporator independently of the operation of the refrigeration system.

Yet another object of this invention is to provide method and apparatus for regenerating a refrigerant-lubricant mixture in a compressor-condenser, evaporator refrigeration system in which lubricant is continuously separated from a determined volume of refrigerant-lubricant mixture in a fractionating still and wherein the energy required in the still is utilized to preheat the refrigerant-lubricant mixture to be regenerated.

In general the method of operating a refrigeration system of the compressor, condenser, evaporator circuit type in which lubricant used in the compressor is soluble in the circulated refrigerant forming a refrigerant-lubricant mixture in the system in accordance with the principles of this invention may comprise the steps of: selectively removing a determined volume of said refrigerant-lubricant mixture from said evaporator; heating said determined volume of said refrigerant-lubricant mixture to vaporize and thereby separate said refrigerant from said lubricant; liquefying said vaporized refrigerant so separated; and returning said liquefied refrigerant to said condenser in said refrigeration system whereby said refrigerant is continuously separated from a determined volume of said refrigerant-lubricant mixture and substantially pure liquid refrigerant returned to said refrigeration system independently of the operation thereof.

Apparatus in accordance with the principles of this invention may include a compressor, means for lubricating the compressor, a condenser, and an evaporator operatively connected to provide a refrigeration system. A regenerator, including means for selectively and continuously removing determined volumes of refrigerant-lubricant in a cyclic manner from the evaporator is provided. In general the regenerator comprises a fractionating still including a bath of lubricant and means for heating the bath such that when the refrigerant-lubricant mixture is passed into the still the lubricant goes into the bath where it is returned to the compressor. The refrigerant is vaporized and withdrawn by the suction of an auxiliary compressor through a heat exchanger through which the refrigerant-lubricant mixture is passed and preheated prior to flowing into the still.

Refrigerant vapor withdrawn by the auxiliary compressor is passed into an auxiliary condenser where it is liquefied before flowing back into the main condenser. Electrical control means are provided for regulating a heat source, such as an electrical heating element in the still, and a refrigerant-lubricant mixture control valve wherein the valve is open when the still bath exceeds a determined temperature thus allowing the refrigerant-lubricant mixture to flow from the evaporator into the regenerator. When the still bath temperature falls below the determined value, the control valve is closed and the heating element energized to raise the still bath temperature.

A plurality of decanting lines selectively control the flow of refrigerant-lubricant mixture from the evaporator into the regenerator wherein that refrigerant-lubricant mixture to be regenerated is taken throughout the liquid level within the evaporator.

Control means may be provided for sensing the separation levels or the degree of solubility of lubricant in refrigerant of the respective liquids, refrigerant and lubricant, forming the mixture in the evaporator, and for controlling valves in said decanting lines wherein the refrigerant-lubricant mixture is selectively removed from the evaporator at the liquid level where there is the greatest concentration of lubricant—thus greatly increasing the efficiency of the regenerator.

These and many other objects and advantages of this invention will become apparent from the following detailed description when read in view of the appended drawings wherein:

FIGURE 1 is a schematic of a preferred embodiment of the invention illustrating a refrigeration system of the compressor, condenser, evaporator circuit type including a regenerator; and

FIGURE 2 is an electrical schematic for the control circuit of the preferred embodiment of a regenerator in accordance with the principles of this invention; and

FIGURE 3 is a graph illustrating refrigerant-lubricant solubility curves for different lubricants at varying temperature ranges.

Referring now to the drawings, FIGURE 1 illustrates a preferred embodiment of a refrigeration system in accordance with the principles of this invention as generally comprising a conventional main compressor of the reciprocating piston type for instance, a main condenser 12 and an evaporator or chiller 13 operatively connected to provide a large capacity low temperature refrigeration system. The refrigerant may be of any commercial type and the lubricant for the main compressor 11 may be a paraffin or naphthene base oil. The main compressor 11 as is well known may be controlled by pressure actuated switches connected to the compressor motor (not shown) to control operation of the compressor 11 within predetermined pressure limits in the lines 14 and 16. The hot refrigerant in a gaseous state and including oil vapor, mist and droplets picked up in the compressor 11 from lubricant supplied the compressor from an oil reservoir 17 flows through a stop valve 18 into line 16 and an oil trap 19 where a portion of the oil carried by the gaseous refrigerant is removed and returned by way of filter 21 to the main oil reservoir 17. The compressor lubrication system may also include a suitable sensing element 22 for maintaining the oil level 23 within the compressor 11 at a determined value to assure proper lubrication.

The trap 19 which may be a conventional surge drum is partially effective but because of the miscibility of refrigerant and lubricant, lubricant continues to build up in the gaseous refrigerant and is carried with the hot refrigerant gas through check valve 15 into the condenser 12. Because of the temperature and the pressure within the condenser 12 lubricant from the compressor 11 is readily soluble in the liquefied refrigerant and there is no separation into liquid layers. The liquefied refrigerant including lubricant dissolved therein is passed through a suitable storage reservoir 24 by way of conduits 26 which provide top and bottom relief valve lines to the atmosphere, and relief or safety valves 27 before flowing through drier 28 into the evaporator 13 by way of conduit 29. An electric solenoid control valve 31 is provided for shutting down the system. A sight glass 32 may also be provided in the line 29.

The liquefied refrigerant-lubricant mixture flows into the chiller or evaporator 13 where it achieves a liquid level 33. As is well known the liquid refrigerant in the evaporator is vaporized as it flows in heat exchange relation with the evaporator walls or a cooling medium flowing inside a closed circuit. In systems where there is not enough head room in the evaporator, the gaseous refrigerant then flows into a knock-out drum 34. From the knock-out drum 34, the gaseous refrigerant, because of the suction in line 14 created by the main compressor 11, flows through a back pressure valve 36 into suction trap 37 by way of line 38. From the trap 37, gaseous refrigerant is returned to the main compressor while any lubricant separated therefrom is returned by way of oil return line 39. A vent line 41 is provided between the oil reservoir 17 and trap 37.

The foregoing describes a conventional refrigeration system of the compressor, condenser, evaporator circuit type, including the use of well known oil separators or traps for

removing lubricant from the resulting refrigerant-lubricant mixture that builds up in the system. The operation of this portion is well known and need not be described in further detail. In spite of the use of oil traps, filters and the like build-up of lubricant in the refrigerant because of the two liquids miscibility continues to be a critical problem, ultimately requiring the system to be shut down so the oil may be purged and returned to the compressor oil reservoir. As stated, because of the temperatures and pressures involved, the solubility of lubricant in the refrigerant is generally no problem at the condenser provided sufficient lubricant is maintained in the compressor lubrication system. However any lubricant in the refrigerant effects the efficiency of the refrigeration system as it impedes the requisite heat transfer at the evaporator and thus the cooling capacity. In large, low temperature systems the presence of lubricant in the evaporator liquid is especially critical as the refrigerant ultimately separates into liquid layers, lubricant at the top and refrigerant at the bottom.

FIGURE 3 illustrates typical critical temperature, solubility curves of a number of different grade, commercially available lubricants in refrigerant. As shown in FIGURE 3, the area above the respective curves is the region where the refrigerant and lubricant are miscible or soluble and the area below the respective curves that region where the refrigerant and lubricant have a tendency to separate into separate layers. In operation, especially at low temperatures, all lubricants have a tendency to become viscous and come out of solution. Because of varying temperature and pressure in the evaporator the transition into separate liquid layers of refrigerant and lubricant is not instantaneous or uniform throughout the liquid level within the evaporator. Therefore before the critical or separation temperature is reached, there may be separate liquid layers of lubricant in the evaporator—particularly where the mixture is 10-50% by weight of lubricant.

Referring again to FIGURE 1 a regenerating system is provided for separating any lubricant and returning pure liquefied refrigerant to the condenser 12 and lubricant to the main compressor oil reservoir 17 independently of the operation of the refrigeration system. A plurality of preferably equal sized decanting lines 42, each provided with a control valve 43, extend at varying levels into the evaporator 13 from the bottom of the evaporator to the top of the liquid level of refrigerant-lubricant mixture therein. A liquid level control means 44 such as a Spolten Level Master, manufactured by Spolten Valve Company of St. Louis, Mo., or other similar device is provided to maintain the correct liquid level for the desired operating temperatures and pressures. Conduits 40 provide for the pressure equalization control of the level sensing control means 44. Sensing means may be provided in the evaporator 13 for sensing the separation of lubricant and refrigerant into layers within the evaporator and actuate the decanting line valves to open that valve and decanting line adjacent the lubricant layer and close the remaining control valves. In a preferred embodiment an ultrasonic transducer element 50 may be inserted in each decanting line 42 and arranged to operate the respective solenoid valves 43 when the oil concentration or density of the evaporator at that level reaches a determined level. Other known devices such as a conductivity cell, or a differential pressure and density control valve may also be employed. In this manner a determined volume of refrigerant-lubricant having the greatest percent by weight of lubricant is selectively removed from the evaporator and passed through a solenoid control valve 45 in line 46, heat exchanger 47, and into a regenerator or fractionating still 48. The decanting lines 42 may also be used without the sensing means for actuating the control valves 43, by opening all of these valves and thus selectively removing a determined volume of refrigerant-lubricant mixture from throughout the liquid level in the evaporator. By removing liquid from through-

out the evaporator, the separation and formation of lubricant layers in the evaporator 13 is avoided.

The regenerator of fractionating still 48 is provided with a manual control valve 49 for adding oil to the bath 51 which is maintained at the desired level by means of a standpipe 52 which returns any overflow to the main oil reservoir 17 and the compressor 11 by way of control valve 53 and line 54. A heater, such as an electrical heating element 56, is provided for heating the oil bath 51 and is provided with a thermostatic control switch 57 for turning off the heater when the bath reaches a determined temperature.

The heated liquid refrigerant-lubricant mixture passes from the heat exchanger 47 through a line 55 into the still where the heat of the oil bath vaporizes the refrigerant and the lubricant goes into the bath and as noted returns to the oil reservoir 17. An auxiliary compressor 58 creates a suction in line 59 to draw the heated refrigerant vapor through the exchanger 47 where it passes in heat exchange relationship with the refrigerant-lubricant mixture flowing into the regenerator 48. The compressed gas passes from the auxiliary compressor 58 through an oil filter 61 into an air cooled condenser 62 where it is liquefied before returned to the main condenser 12 by way of line 63.

FIGURE 3 is an electrical schematic of the control circuit of the regenerating system and as shown the compressor 58 is protected with high and low pressure switches 64 and 66 to assure operating within determined limits. As shown, relay 67 is provided in circuit with thermostat 57 and is provided with normally closed contacts 67-1, connected in series with heater 51 and normally open contacts 67-2 in series with solenoid control valve 45. In operating it is necessary to first bring the still bath 51 to the desired temperature thus thermostat 57 is open and contacts 67-1 closed and the heater 56 energized. At this time contacts 67-2 are open and valve 45 closed so there is no flow from the evaporator 13 into the heat exchanger 47. When the oil bath 51 reaches the determined temperature thermostat switch 57 closes energizing relay 67 to open contacts 67-1 and close contacts 67-2 to turn off the heater 56 and open valve 45. A determined volume of refrigerant-lubricant mixture selectively removed from the evaporator 13 through valve or valves 43 and decanting lines 42 then flows into the regenerator 48 where the lubricant is removed and vaporized refrigerant drawn off by the auxiliary compressor 58.

In operation heating element 56 is chosen of sufficient size so that bath warming time is short and the valve 45 closed only for brief intervals. Consequently start up time is minimum and regeneration of the refrigerant-lubricant mixture is substantially continuous. Because of the independent operation of the regenerating system, it may be used to pump down the evaporator 13 and regenerate and return all refrigerant to the condenser 12 automatically when the main system is not in operation. Further the invention may be readily adapted to existing refrigeration systems. In operation it has been found that lubricant can practically be eliminated from refrigeration systems using the method and apparatus of this invention.

Although a preferred embodiment of refrigeration method and apparatus in accordance with this invention have been described in detail, numerous changes and modifications may be made within the principles of the invention which is to be limited only by the appended claims.

What is claimed is:

1. The method of operating a refrigeration system of the compressor, condenser, evaporator, circuit type in which lubricant used in the compressor is soluble in the circulated refrigerant forming a refrigerant-lubricant mixture in the system comprising the steps of: selectively removing a determined volume of said refrigerant-lubricant mixture from said evaporator; heating said determined volume of refrigerant-lubricant mixture to vaporize and thereby separate said refrigerant from said lubricant; liquefying said vaporized refrigerant so separated; and returning said liquefied refrigerant to said condenser in said

refrigeration system whereby said refrigerant is continuously separated from a determined volume of said refrigerant-lubricant mixture and substantially pure liquid refrigerant returned to said refrigeration system independently of the operation thereof.

2. The method of claim 1 including the step of returning said lubricant separated from said refrigerant-lubricant mixture to said compressor.

3. The method of claim 1 wherein said second step comprises: passing said refrigerant-lubricant mixture into a regenerating chamber containing a bath of said lubricant; maintaining said lubricant in said bath at a temperature sufficient to vaporize said refrigerant in said mixture directed into said regenerating chamber whereby said lubricant in said refrigerant-lubricant mixture is separated therefrom and goes into said lubricant bath; and withdrawing said vaporized refrigerant from said regenerating chamber.

4. The method of claim 3 wherein the vaporized refrigerant removed from said regenerating chamber is passed in a heat exchanging relationship with said refrigerant-lubricant mixture removed from said evaporator and passed into said regenerator.

5. The method of claim 1 wherein said determined volume of refrigerant-lubricant mixture is selectively removed from said evaporator at a plurality of spaced positions.

6. The method of claim 5 including the steps of: sensing the percent of solubility of lubricant in refrigerant at spaced levels within said evaporator and withdrawing said determined volume of refrigerant-lubricant mixture from said evaporator at said level within said evaporator having the greatest percentage of solubility of lubricant in refrigerant.

7. In a refrigeration system of the compressor, condenser, evaporator, circuit type employing a lubricant miscible in a refrigerant forming a refrigerant-lubricant mixture the improvement comprises: a regenerator for separating said lubricant from said refrigerant; means operatively connected between said evaporator and said regenerator for selectively removing a determined volume of said refrigerant-lubricant mixture from said evaporator and passing said mixture into said regenerator; means for withdrawing vaporized refrigerant from said regenerator; and means for liquefying said vaporized refrigerant and returning substantially pure liquid refrigerant to said condenser independently of the operation of said refrigeration system.

8. Apparatus as defined in claim 7 including: a heat exchanger interconnected between said evaporator and said regenerator for preheating said refrigerant-lubricant mixture prior to its entry into said regenerator.

9. Apparatus as defined in claim 8 wherein said vaporized refrigerant in said regenerator is withdrawn through said heat exchanger and passed in a heat exchange relationship with said refrigerant-lubricant mixture thereby heating same.

10. Apparatus as defined in claim 7 wherein said means operatively connected between said evaporator and said regenerator for selectively removing a determined volume of said refrigerant-lubricant mixture from said evaporator and passing said mixture into said regenerator comprises: a plurality of decanting lines extending in said evaporator and at spaced intervals therein for selectively withdrawing said refrigerant-lubricant mixture from a liquid level within said evaporator.

11. Apparatus as defined in claim 10 wherein said decanting lines each include a control valve; and means within said evaporator for sensing lubricant concentrations in said evaporator and for selectively opening said valve in said decanting line nearest thereto.

12. Apparatus as defined in claim 7 wherein said regenerator comprises: a still having a lubricant bath therein; means for heating said bath to a determined temperature; means for sensing the temperature of said bath and

turning off said heating means; a control valve interconnected between said evaporator and said regenerator; and means responsive to said temperature sensing means for maintaining said control valve open when said bath exceeds a determined temperature and closes said control valve when said bath temperature is below said determined valve and for turning on said heater.

13. Apparatus as defined in claim 7 wherein said means for withdrawing vaporized refrigerant from said regenerator comprises: an auxiliary compressor and said means for liquefying said vaporized refrigerant comprises an auxiliary condenser both of which are operative independently of said refrigeration system.

14. A refrigeration system comprising: a compressor; a condenser; an evaporator, said compressor, condenser and evaporator being connected in circuit for circulating a refrigerant in said system, said compressor utilizing a lubricant miscible in said refrigerant forming a refrigerant-lubricant mixture in said refrigeration system; a regenerator comprising a fractionating still and including a bath therein and means for maintaining said bath at a determined temperature; a plurality of spaced decanting lines extending into said evaporator and connected to said regenerator for selectively removing a determined volume of refrigerant-lubricant mixture from throughout said evaporator and passing said refrigerant-lubricant mixture to said regenerator; a control valve interconnected between said decanting lines and said regenerator; temperature sensing means for detecting the temperature of said bath; means responsive to said temperature sens-

ing means for opening said control valve and turning off said heating means when said bath temperature reaches a determined maximum value whereby refrigerant in said refrigerant-lubricant mixture flowing into said still is vaporized and said lubricant in said refrigerant-lubricant mixture goes into said bath in said still; means for returning said lubricant in said bath to said compressor; means for withdrawing said vaporized refrigerant in said still; and means for liquefying said vaporized refrigerant and returning said liquefied refrigerant to said condenser.

15. Apparatus as defined in claim 14 including a heat exchanger interconnected between said evaporator and said regenerator and wherein said vaporized refrigerant in said regenerator is withdrawn in a heat exchange relationship with said refrigerant-lubricant mixture in said heat exchanger whereby said refrigerant-lubricant mixture is preheated prior to entry into said regenerator.

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