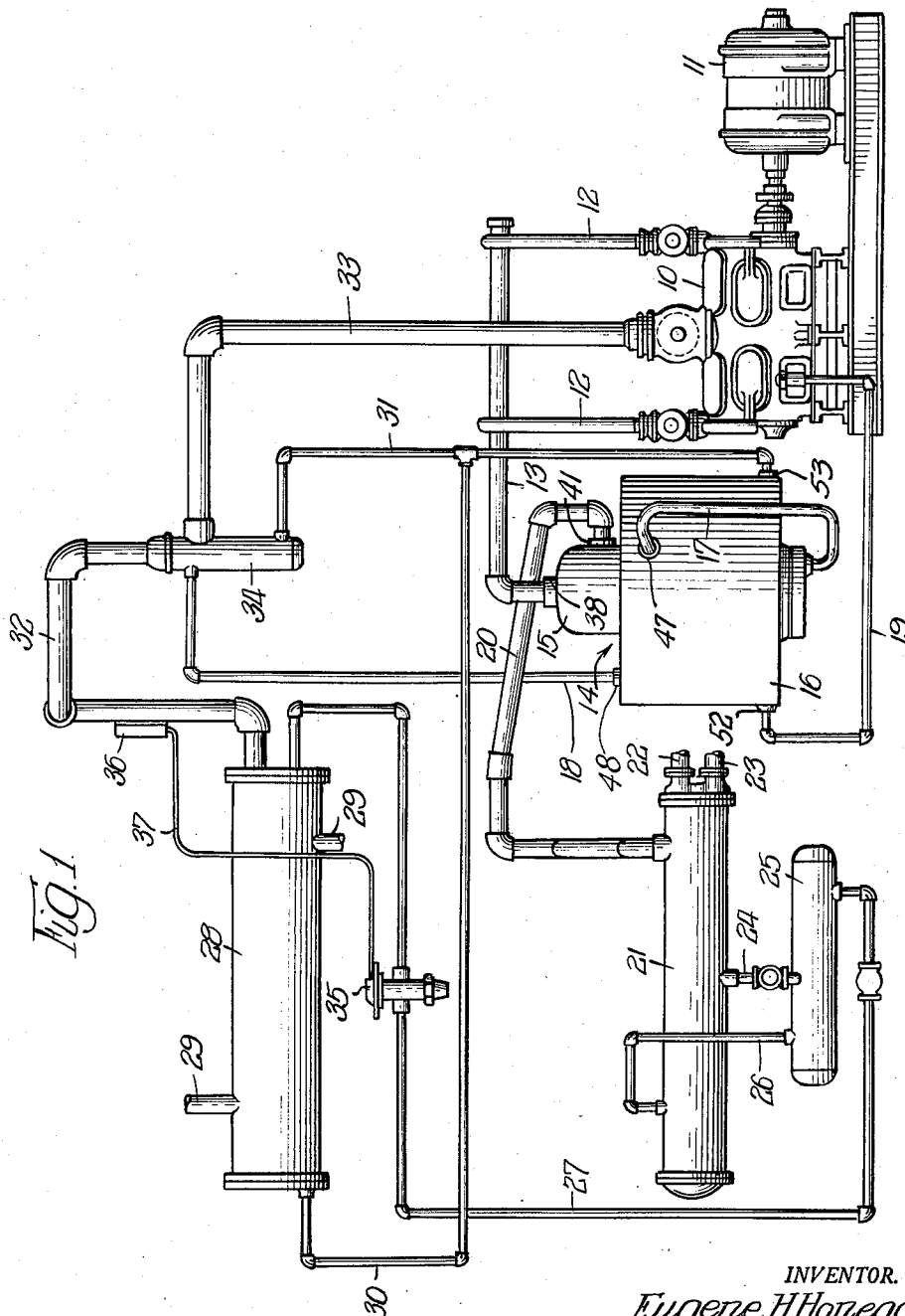


Aug. 25, 1959 **E. H. HONEGGER** **2,900,801**
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IN REFRIGERATION SYSTEM
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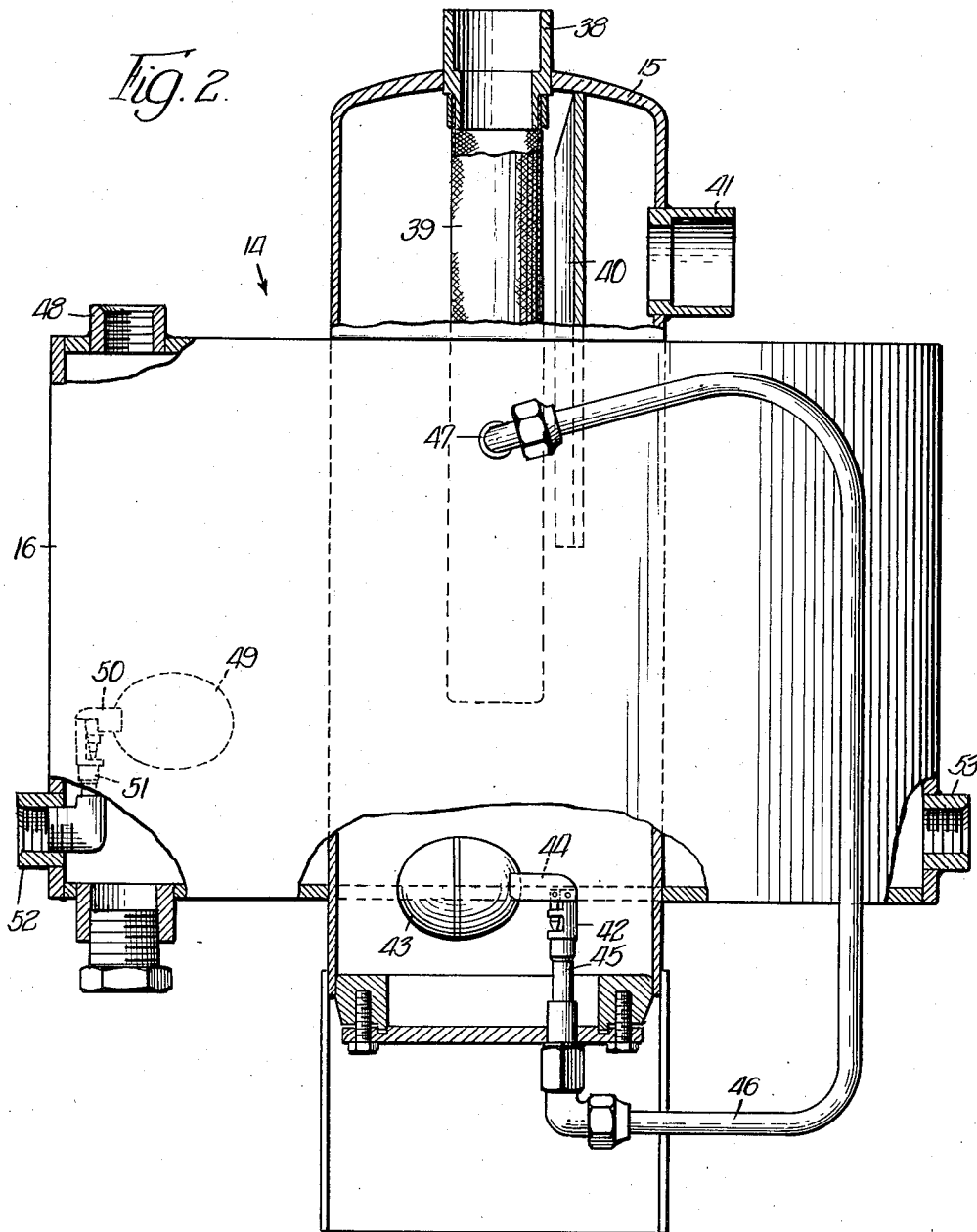
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METHOD AND APPARATUS FOR OIL SEPARATION IN REFRIGERATION SYSTEM

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10 Claims. (Cl. 62—84)

The present invention relates generally to a method and apparatus for use in a refrigeration system whereby the operation of the system is substantially improved. More specifically, the invention is directed to a method of separating liquid from gaseous refrigerant and recovering refrigerant retained by the separated liquid, which method has particular application for use in the separation and purification of lubricating oil picked up by the refrigerant during the compression thereof. Still further the invention includes one form of apparatus particularly capable of carrying out the aforementioned method.

In the operation of known closed refrigeration systems the lubricant used in the refrigerant compressor becomes mixed at least to a certain extent with the gaseous refrigerant and circulated with the refrigerant through the system. The extent of mixing depends upon the type of refrigerant as well as the design of the refrigerant compressor. Where the compressor is well designed the quantity usually does not exceed 2% of the amount of refrigerant circulated. However, the continual removal of even small quantities of lubricant without its ultimate return depletes the oil reserve in the compressor and the operation of the compressor is jeopardized. Furthermore, the accumulation of free lubricant in other portions of the system will affect the thermodynamic characteristics of the original design to decrease the efficiency of the system. If the lubricant should accumulate in any one part of the system the formation of a slug often results and the return to the compressor of a slug of lubricant can result in damage to the compressor itself depending upon the size of the slug.

Refrigerants such as monochlorodifluoromethane and dichlorotetrafluoroethane are miscible with oil under certain conditions of temperature and pressure. For instance, monochlorodifluoromethane is miscible with oil in the high temperature side of a refrigeration system but not in the low temperature side existing in the cooling coil. As a result, two layers of liquid are formed in the cooling coil side with the oil floating on top of the liquid refrigerant. Under such conditions it is quite possible for an accumulation of oil to occur in the system with the further possibility of the formation of a partially solidified oil slug which, if delivered to the compressor, can result in the damaging thereof.

The mixing of refrigerant and lubricant in the compressor creates an additional problem over and above those of depletion of compressor lubricant supply and lubricant slug formation. Many of the widely used refrigerants, particularly the halogenated hydrocarbon derivatives, are completely miscible with lubricating oil under all operation conditions. Examples of such refrigerants are as follows:

Trichloromonofluoromethane
Dichlorodifluoromethane
Dichloromonofluoromethane
Monochlorodifluoromethane
Trichlorotetrafluoroethane

2

Dichlorotetrafluoroethane
Methylene chloride

As a result the oil is diluted by the refrigerant and its viscosity and lubricating efficiency is decreased. Provisions have been made for the separation of lubricating oil from the refrigerant in various systems but in many instances the separated oil has either been withdrawn from the system and discarded due to its reduced effectiveness or returned to the compressor in its diluted state. The latter procedure ultimately results in damage to the compressor due to the decreased lubricating ability of the returned oil. An additional disadvantage exist in following this procedure in that upon a reduction in pressure on the oil there often occurs a sudden release of refrigerant from solution accompanied by considerable foaming which, if occurring in the crankcase of a compressor, will cause the oil to be thrown into the system accelerating the loss thereof.

Various types of oil separators have been used in refrigeration systems. While many of these are capable of separating the bulk of the oil from the gaseous refrigerant they are nevertheless incapable of separating gaseous and liquid refrigerant miscible with the oil. Furthermore, where refrigerants such as monochlorodifluoromethane and dichlorotetrafluoroethane are used, oil not removed by the separator will eventually separate out in the low temperature side of the system. Any oil accumulation occurring under these circumstances must be removed from the point of accumulation to prevent the formation of slugs. Still further, the accumulated oil should be treated to remove residual refrigerant before recycling to the compressor. Known separator apparatus is incapable of carrying out these necessary functions and in many instances expensive procedures have been relied upon to overcome these difficulties.

It is an object of the present invention to overcome the aforementioned difficulties resulting in the picking up of liquids such as lubricating oil by the refrigerant by the provision of a method which, upon use, is capable of efficiently and inexpensively separating refrigerant from liquid and, in the instance where the liquid is lubricating oil, reclaiming refrigerant miscible in the oil before returning the oil to the compressor in a state wherein its lubricating properties have been preserved.

A further object is to make use of the heat of compression of the refrigerant immediately following the compression thereof to aid in the substantially complete separation of gaseous refrigerant from compressor lubricating oil in such a manner as to allow the oil to be returned directly to the compressor without further treatment and without appreciable depletion in the compressor oil supply while at the same time reclaiming gaseous refrigerant from the oil for further use in a refrigeration system without the requirement of introducing additional energy into the system.

Still another object is to provide a form of apparatus capable of carrying out the aforementioned objects, which apparatus is simply constructed, manufactured at low cost, efficient in operation and readily adapted for use in many different types of refrigeration systems.

Other objects not specifically set forth will become apparent from the following detailed description made in connection with the drawings wherein:

Fig. 1 illustrates a refrigeration system capable of carrying out the method of the present invention and having incorporated therein one form of an oil separator-accumulator unit forming a part of the present invention; and

Fig. 2 is an elevation in partial section of the separator-accumulator unit of Fig. 1.

It is the primary purpose of the present invention to make use of the heat of compression of gaseous re-

frigerant in bringing about a substantially complete separation of refrigerant from liquid such as lubricating oil. This purpose may be accomplished by passing the compressed gaseous refrigerant containing quantities of liquid such as lubricating oil directly from the compressor into a separation zone wherein the bulk of the liquid is separated from the refrigerant in a known manner. The separated liquid is then delivered into an accumulation zone which is maintained in heat exchange relation with the separation zone thereby utilizing the heat of compression to retain the high temperature of the liquid. The accumulation zone is further maintained under a pressure substantially less than that existing in the separation zone and the action of the heat attained by exchange along with the reduced pressure conditions forces gaseous and liquid refrigerant retained by the liquid to separate therefrom thereby recovering refrigerant as well as purifying the liquid. In the instance where oil is the liquid, the oil is purified to an extent that its viscosity and lubricating properties are restored while at the same time reducing refrigerant loss and the purified oil may then be reintroduced directly into the crankcase of the compressor without any appreciable loss thereof or the need to replenish the compressor oil supply from an outside source.

In addition to the foregoing, it is still further desired to entrap any additional liquid such as lubricating oil mixed with the gaseous refrigerant which was not separated in the separation zone and which may very readily collect in low spots throughout the remainder of the refrigeration system such as occur in the condensing or expansion zones. These additional quantities of liquid are delivered to the accumulating zone and treated in the same manner above described. As a result of this procedure it is necessary merely to provide a known refrigeration system with an accumulation zone capable of utilizing the heat of compression of the refrigerant. It is unnecessary to provide such a system with separate heating elements for the purpose of heating the liquid to drive off gaseous refrigerant miscible therein. This latter procedure not only increases the operational costs of the system but also increases maintenance costs arising from the necessity of removing undesirable oil carbonization deposits from the heating elements. Still further, the elimination of slug formation as well as liquid accumulation of any type maintains the efficiency of the total system and at the same time eliminates the possibility of serious damage to the compressor as a result of semi-hardened slugs being forced thereinto.

The operation of a typical refrigeration system modified to carry out the method of the present invention will now be described in connection with the removal of compressor oil from gaseous refrigerant. However, it should be understood that the method may be used to recover most any liquid.

The system shown in Fig. 1 includes a compressor 10 suitably coupled to a driving motor 11. The compressor 10 is provided with hot gas discharge lines 12—12 which move the compressed gaseous refrigerant into a line 13 from which the refrigerant flows into a separator-accumulator unit 14. The unit 14 is composed generally of a centrally located oil separator 15 which is surrounded by an outer annular accumulator 16 maintained in heat exchange relation with the separator 15. The separator 15 is of known design and will be more fully described along with the accumulator 16 in connection with Fig. 2.

The hot gaseous refrigerant carrying quantities of lubricating oil from the compressor 10 is introduced into the separator 15 wherein it follows a tortuous flow path and contacts a screen element on which liquid lubricant accumulates. The accumulated lubricant eventually collects within the bottom of the separator 15 and due to the high gas pressure within the separator 15, the gaseous refrigerant miscible in the oil cannot escape therefrom

and as a result the oil is in a diluted state. Control means are provided in the oil zone of the separator 15 and upon the attainment of a predetermined quantity of oil therein a valve is opened and oil is forced by means of the high pressure maintained therein through line 17 from the bottom of the separator 15 into the accumulator 16 near the top thereof. The oil is collected within the accumulator 16 under a pressure substantially less than that maintained within the separator 15.

Due to the arrangement of the accumulator 16 in heat exchange relation with the separator 15, the heat of compression of the hot gas flowing through the separator 15 is utilized to maintain the temperature of the oil in the accumulator 16. As a result of the reduced pressure and the maintenance of the high temperature, liquid and gaseous refrigerant miscible with the oil is driven from the oil and passed from the accumulator 16 through line 18 to be added to gaseous refrigerant at a suitable point in the system to be described. An additional control means may be provided in the accumulator 16 to control the level of oil therein and to further allow a portion of the oil from which refrigerant has been removed to recycle to the crankcase of the compressor 10. An oil line 19 extends from the bottom portion of the accumulator 16 to provide means for returning the oil by gravity flow to the crankcase of the compressor 10.

The separator 15 is further provided with a refrigerant outlet line 20 which removes gaseous refrigerant therefrom near the top portion thereof to a condensing zone making use of a condenser 21 of a known type. Lines 22 and 23, partially shown in Fig. 1, are suitably connected to a source of coolant which is delivered into heat exchange relation with the gaseous refrigerant to condense the same in the known manner. The condenser 21 is further provided with a liquid drain 24 for delivering liquified refrigerant into a receiver tank 25 provided with gas flow return means 26 of conventional design. From the receiver 25 the liquid refrigerant is conducted through line 27 into an expansion chiller 28 of known type or any form of cooling coil wherein the refrigerant is allowed to expand in heat exchange relation with a liquid or gas to be cooled entering and leaving through the partially shown conduits 29—29.

During the expansion of the liquid refrigerant in the chiller 28 some entrained oil may separate from the refrigerant and collect therein. In order to alleviate slug formation and maintain the efficiency of the system a line 30 is provided to drain the chiller 28 of any collected oil therein. The line 30 conducts the oil to a drain line 31 through which the oil is introduced into the accumulator 16. The small quantities of oil collected from the chiller 28 are then subjected to the high temperature-low pressure conditions of the accumulator 16 and substantially clarified of refrigerant prior to recycling to the crankcase of the compressor 10.

The expanded refrigerant is moved from the chiller 28 through line 32 and is introduced at right angles into a suction line 33 through which it travels into the suction side of the compressor 10 to be recompressed and recycled. The right angle connection between the lines 32 and 33 is provided with a dead-end oil trap 34 which collects any residual oil that might possibly still be carried by the gaseous refrigerant. Any oil collected in the trap 34 is returned through the line 31, which is suitably connected with the trap 34 into the accumulator 16 for high temperature-low pressure treatment as previously described.

Line 18 is connected to the suction line 33 to reintroduce gaseous refrigerant recovered from the oil in the accumulator 16 into the system. This line also acts as a pressure equalizing line between the suction side of the compressor 10 and the accumulator 16. In this manner the accumulator 16 is maintained under a reduced pressure thereby aiding the escape of refrigerant from the accumulated oil. From this it can be seen that

the operative features of the system are utilized to great advantage. No additional energy requirements are necessary to bring about a substantially complete separation of refrigerant from oil and the return of these separated components to the place of performance of their intended functions in the operation of the system. The system described includes a conventional expansion valve 35 in the line 27 to control the flow of liquid refrigerant into the chiller 28 in response to the pressure-temperature conditions in the line 32 which affects a control 36 operating the valve 35 through a control line 37.

From the foregoing description it can be seen that the operation of a refrigeration system incorporating the principles of the present invention may be maintained at a high level of efficiency due to substantially complete removal of lubricating oil from the refrigerant. The oil recovered is adequately treated to revive its lubricating properties and returned directly to the compressor for further use. As a result there is little if no loss of lubricating liquid from the system. Furthermore, there is little if no loss of refrigerant resulting from its mixing with the oil. Moreover, existing refrigeration systems may be readily modified without substantial expense to adapt the systems for carrying out the above described method of oil separation. In the system of Fig. 1 various operating valves, drains, automatic controls and the like have not all been shown for the purpose of simplifying the description thereof. Obviously, these necessary elements may be readily incorporated in the system in accordance with known practices.

In Fig. 2, one form of a separator-accumulator unit 14 is shown. As previously described in connection with Fig. 1, the unit 14 includes a centrally located separator 15 surrounded annularly thereof by an accumulator 16. The latter unit is closely associated with the separator 15 to allow the exchange of heat through the outer wall of the separator 15 with oil collected in the accumulator 16. The separator 15 is of known design and includes a body shell having a centrally located inlet 38 in the top thereof through which compressed gaseous refrigerant is delivered from the compressor. The hot gases flow downwardly into the separator 15 internally of a screen 39 of small mesh mounted about the inner extension of the opening 38. The gaseous refrigerant passes into contact with the screen 39 and particles of oil are deposited thereon which ultimately collect in sufficient mass to fall therefrom into the bottom of the separator 15. The gaseous refrigerant flows downwardly to a point below a baffle 40 arranged vertically within the separator 15 to one side of the screen 39. Upon reaching the bottom of the baffle 40 the direction of flow of the refrigerant is drastically modified and the gases are allowed to flow upwardly between the baffle 40 and the side wall of the separator 15. The refrigerant then leaves the separator 15 through the opening 41 in the side thereof near the top portion thereof. The opening 41 is connected to a line which directs the gaseous refrigerant to a suitable condenser.

The gaseous refrigerant and the separated oil collected in the bottom of the separator 15 are under substantially the same pressure as the outlet pressure of the compressor. As a result an amount of refrigerant is retained by the oil either in a gaseous or liquid state due to the miscibility of the refrigerant in the oil. Upon the accumulation of a sufficient quantity of oil in the bottom of the separator 15, a needle valve 42 is opened by a float 43 suitably connected thereto by a valve operating arm 44 and a quantity of oil flows through a pipe 45 extending through the bottom of the separator 15. The high pressure within the separator 15 forces the oil through a line 46 in an upwardly direction to an opening 47 in the accumulator 16 near the top thereof. As a result of this arrangement a quantity of oil is delivered into the accumulator 16 and maintained therein at substantially the same temperature due to the heat exchange

relation existing between the accumulator 16 and the separator 15 and under a reduced pressure. The pressure maintained in the accumulator 16 is substantially that of the suction end of the compressor associated therewith and as a result is substantially less than the pressure of the separator 15. Due to the maintaining of a relatively high temperature and reduced pressure condition, liquid and gaseous refrigerant retained by the oil is released thereby and flows from the accumulator 16 through an outlet 48 in the top thereof and is ultimately reintroduced into the refrigeration system.

The accumulated and clarified oil, upon reaching a predetermined depth in the accumulator 16, operates a float 49 connected by a valve operating arm 50 with a needle valve 51. Upon the opening of the valve 51, a quantity of oil is allowed to flow by gravity out of the accumulator 16 through an opening 52 therein near the bottom thereof. The opening 52 and a line suitably connected thereto is arranged to convey the oil removed from the accumulator 16 by gravity flow to the crankcase of the compressor used in the system. The accumulator 16 is further provided with an opening 53 near the bottom thereof to which is attached an oil drain line running from various points in the refrigeration system through which trapped quantities of oil are removed from the system to the accumulator 16. As previously described, the oil introduced into the accumulator 16 through the opening 53 is subjected to the same treatment as that received directly from the separator 15.

The separator-accumulator unit 14 may take various forms as long as the oil accumulation portion is capable of making use of the heat of compression given off by the separator portion to separate refrigerant mixed with the oil. If desired, the separator-accumulator unit 14 may be placed in a horizontal position rather than the vertical position shown in the drawings to conform with the space requirements of a given refrigeration system. Under such circumstances it would be necessary merely to change the locations of the float control valves while at the same time arranging the piping between the accumulator 16 and the compressor to provide for gravity flow of oil therebetween. Obviously other types of valves may be made use of in maintaining proper levels of oil either in the separator 15 or accumulator 16.

In making use of the principles of the present invention, high speed vapor compressors which require precision clearances of moving parts and thereby demand a reliable lubrication system for protection and continued operation may be efficiently used while being assured of a pure oil supply adequate to maintain efficient lubrication. By use of the heat of compression in the manner above described, it is unnecessary to completely externally heat-insulate the oil separator 15 due to the requirement of the transfer of heat between the separator and the accumulator. In existing systems, heat insulation of the separator is necessary to protect operating personnel from contact burns. This additional expense is thereby alleviated in systems incorporating the principles of the present invention. It should be further noted that the separation of liquid from gaseous refrigerant as above described may be carried out completely automatically, and in the course of doing so that total refrigeration system maintained in operation at peak efficiency.

Obviously many modifications and variations of the invention as hereinbefore set forth may be made without departing from the spirit and scope thereof, and therefore only such limitations should be imposed as are indicated in the appended claims.

I claim:

1. A method of separating refrigerant and liquid where the refrigerant is miscible in the liquid comprising passing compressed hot substantially gaseous refrigerant through a separating zone, separating the liquid

7

from said refrigerant in said separating zone, moving said separated liquid from said separating zone into an accumulating zone, maintaining said separated liquid in said accumulating zone in indirect heat exchange relation with hot gaseous refrigerant continuously passing through said separating zone, and removing gaseous refrigerant from said accumulating zone separated from said liquid therein by the heat transferred thereto from said separating zone.

2. A method of separating refrigerant and liquid where the refrigerant is miscible in the liquid comprising passing compressed hot substantially gaseous refrigerant through a liquid separating zone, separating the liquid from said gaseous refrigerant in said separating zone, moving said separated liquid from said separating zone into an accumulating zone which is maintained under a lower pressure than that of said separating zone, maintaining said separated liquid in said accumulating zone in indirect heat exchange relation with the hot gaseous refrigerant continuously passing through said separating zone, and removing gaseous refrigerant from said accumulating zone separated from said liquid therein by the heat transferred thereto from said separating zone.

3. In the operation of a refrigeration system wherein gaseous refrigerant is compressed in a compression zone, passed through a liquid separation zone, condensed, expanded and returned to the compression zone, the additional steps of removing the separated liquid from said separation zone into an accumulation zone, maintaining indirect heat exchange between said liquid in said accumulation zone and newly compressed refrigerant passing through said separation zone, and delivering gaseous refrigerant separated from said liquid in said accumulation zone due to said heat exchange back into said system on the suction side of said compression zone.

4. In the operation of a refrigeration system wherein gaseous refrigerant is compressed in a compression zone while being retained in its gaseous state, passed through a liquid separation zone, condensed, expanded and returned to the compression zone, the additional steps of removing the separated liquid from said separation zone into an accumulation zone which is under a pressure lower than that of said separating zone, maintaining indirect heat exchange between said liquid in said accumulation zone and newly compressed refrigerant passing through said separation zone, and delivery gaseous refrigerant separated from said liquid in said accumulating zone due to said heat exchange back into said system on the suction side of said compression zone.

5. In the operation of a refrigeration system wherein gaseous refrigerant is compressed in a compression zone while being retained in its gaseous state, passed through a liquid separation zone, condensed, expanded and returned to the compression zone, the additional steps of removing the separated liquid from said separation zone into an accumulation zone which is under a pressure lower than that of said separating zone, maintaining indirect heat exchange between said liquid and newly compressed refrigerant passing through said compression zone, introducing trapped liquid from other points in said system into said accumulation zone, and delivering gaseous refrigerant separated from said liquid in said accumulation zone due to said heat exchange back into said system on the suction side of said compression zone.

6. In the operation of a refrigeration system wherein gaseous refrigerant is compressed in a compression zone while being retained in its gaseous state, passed through a compressor lubricant separation zone, condensed, expanded and returned to the compression zone, the additional steps of removing the separated compressor lubricant from said separation zone into an accumulation zone which is under a pressure substantially equal to the suction pressure of said compression zone, maintaining indirect heat exchange between said compressor lubricant

8

and newly compressed refrigerant passing through said compression zone, introducing trapped lubricant from other points in said system into said accumulation zone, delivering gaseous refrigerant separated from said compressor lubricant in said accumulation zone due to said heat exchange back into said system on the suction side of said compression zone, and returning said compressor lubricant to said compression zone.

7. A method of operating a refrigeration system comprising: passing gaseous refrigerant through a compression zone and compressing the same to an extent that said refrigerant retains its gaseous state and yet is on the verge of condensing, separating compressor lubricant from said gaseous refrigerant in a separation zone, accumulating said separated compressor lubricant in a separate accumulating zone under a pressure substantially equal to the suction pressure of the compression zone, maintaining said separated compressor lubricant in indirect heat exchange relation with said gaseous refrigerant passing through said separation zone, passing said gaseous refrigerant through a condensing zone, passing said condensed refrigerant through an expansion zone, removing compressor lubricant collected as a result of the expansion of said condensed refrigerant to said accumulating zone, mixing expanded refrigerant with further gaseous refrigerant separated from said accumulated compressor lubricant as a result of said heat exchange, reintroducing said expanded refrigerant into said compression zone to continue the cycle, and returning said compressor lubricant to said compression zone.

8. A unit adapted for use in a refrigeration system to purify liquid separated from compressed gaseous refrigerant, said unit having liquid separator and liquid accumulator portions, said separator portion including a compressed gaseous refrigerant inlet and outlet, a liquid separating element associated with said inlet, a baffle between said element and said outlet, a sump in said separator portion for collecting liquid removed from said refrigerant, and valve means in said sump for allowing the removal of liquid therefrom, said accumulator portion having inlet means associated with the valve means of said sump, said accumulator portion associated with said separator portion to maintain heat exchange therebetween, and an outlet in said accumulator portion to allow the removal of gaseous refrigerant therefrom.

9. A unit adapted for use in a refrigeration system to purify liquid separated from compressed gaseous refrigerant, said unit having liquid separator and liquid accumulator portions, said separator portion including a compressed gaseous refrigerant inlet and outlet, a liquid separating element associated with said inlet, a baffle between said element and said outlet, a sump in said separator portion for collecting liquid removed from said refrigerant, and valve means in said sump for allowing the removal of liquid therefrom, said accumulator portion attached to the outer surface of said separator portion and being generally U-shaped in cross section, the outer wall of said separator portion serving as the inner wall of said accumulator portion thereby allowing heat exchange between the contents of said separator portion and said accumulator portion, said accumulator portion having inlet means associated with the valve means of said sump to allow the delivery of liquid from said separator portion into said accumulator portion, and an outlet in said accumulator portion to allow the removal of gaseous refrigerant therefrom.

10. A unit adapted for use in a refrigeration system to purify liquid separated from compressed gaseous refrigerant, said unit having liquid separator and liquid accumulator portions, said separator portion including a compressed gaseous refrigerant inlet and outlet, a liquid separating element associated with said inlet, a baffle between said element and said outlet, a sump in said separator portion for collecting liquid removed from said refrigerant, and valve means in said sump for allowing

the removal of liquid therefrom, said accumulator portion attached to the outer surface of said separator portion and being generally U-shaped in cross section, the outer wall of said separator portion serving as the inner wall of said accumulator portion thereby allowing heat exchange between the contents of said separator portion and said accumulator portion, said accumulator portion having inlet means associated with the valve means of said sump to allow the delivery of liquid from said separator portion into said accumulator portion, an outlet in said accumulator portion to allow the removal of gaseous refrigerant therefrom, and means in said accumulator portion for maintaining a predetermined level of liquid therein.

5

10

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