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MULTIPLE COMPRESSOR LUBRICATION APPARATUS

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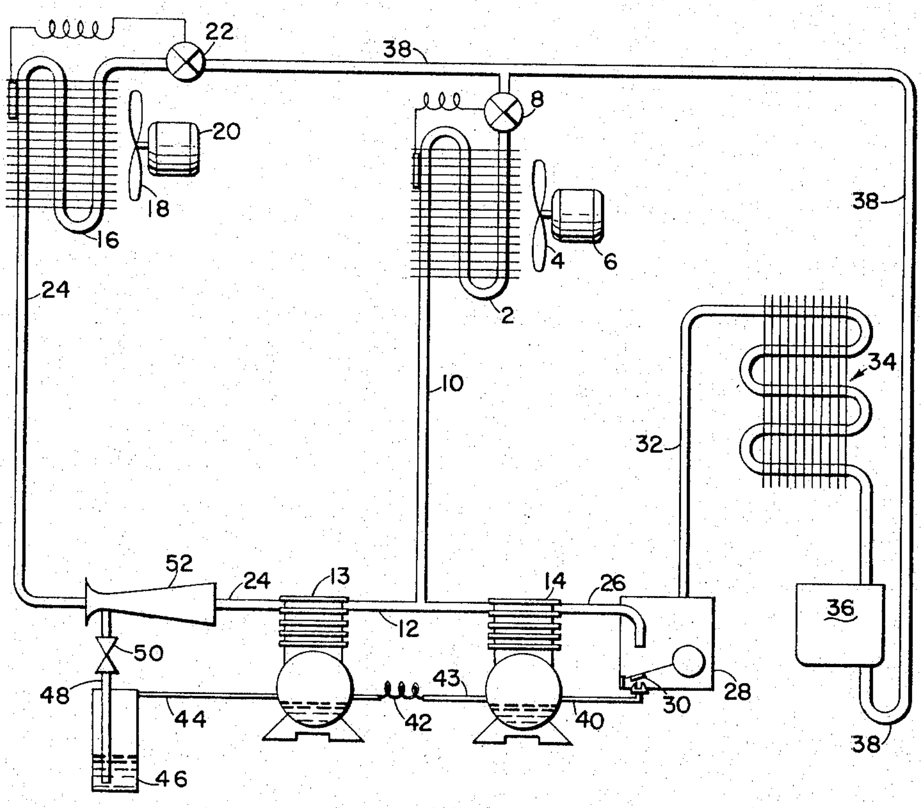

Fig. 1

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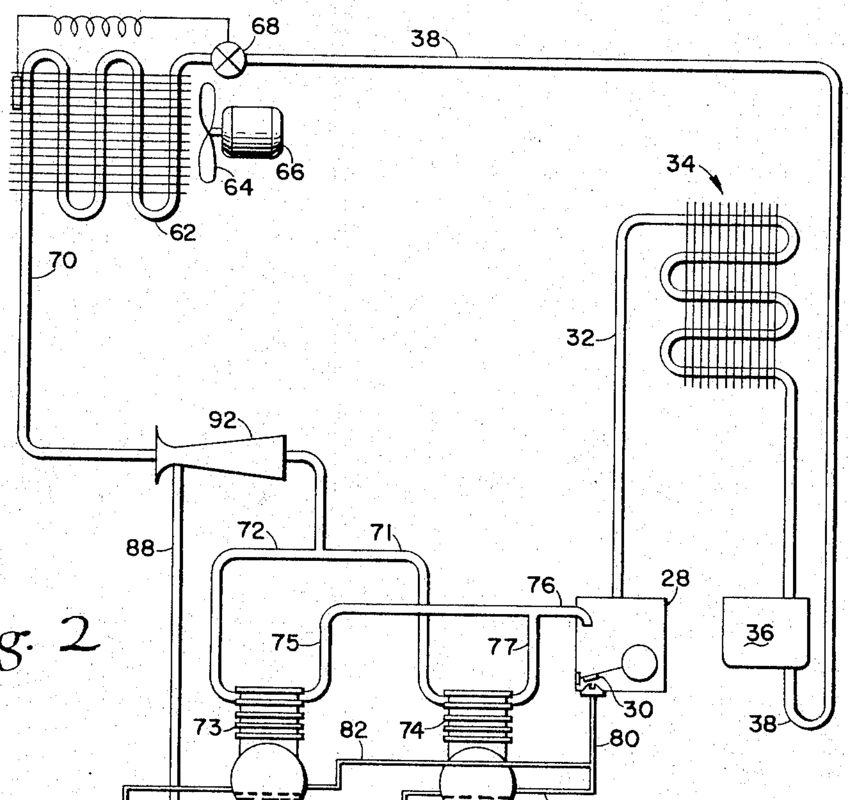

Fig. 2

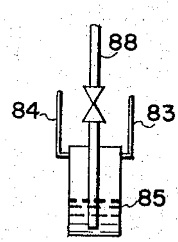

Fig. 3

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MULTIPLE COMPRESSOR LUBRICATION APPARATUS

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ABSTRACT OF THE DISCLOSURE

Oil handling apparatus for a plurality of compressors interconnected in a closed refrigeration circuit comprising an excess oil receiver connected to the crankcases of said compressors at the normal, operating oil level therein and pump means for continuously circulating excess oil from said oil receiver through said compressor crankcases, whereby a reserve supply of circulating oil is readily available to make up any oil deficiency in said crankcases. A suction gas actuated ejector is utilized as the pump means for inducing oil flow from said oil receiver back into said refrigeration circuit.

This invention relates to refrigeration systems employing a plurality of compressors, and more particularly to means for lubricating the bearings and moving parts of such compressors.

There are many refrigeration applications requiring the cooling of zones or products to different temperature levels. A well known example would be a supermarket having display cases for ice cream, which must be kept at a very low temperature on the order of −10° F., and storage cases for dairy products such as milk and eggs which are normally maintained at about 40° F. If the store is to be air conditioned, an additional cooling load at a still higher temperature level exists. Such cooling requirements are quite often met by a refrigeration system incorporating two or more compressors installed in series. The evaporator for the low temperature case is connected to the suction inlet of the first stage or low pressure compressor, and the evaporators for the higher temperature loads are connected to the suction inlets of the successively higher pressure stage compressors. Other applications may call for the installation of two or more compressors in parallel to serve a single evaporator. The lubrication of the moving parts of compressors installed in either manner presents particular problems. As the refrigerant passes through any reciprocating piston compressor a certain amount of the compressor lubricating oil becomes intermixed with the refrigerant due to oil leakage around the compressor pistons and oil foaming up from the refrigerant-oil mixture in the crankcase into the compressor intake valves. It is common practice to utilize an oil separator somewhere in the refrigeration circuit to recover the oil circulating with the refrigerant leaving the compressor and return it to the crankcase. However, oil separators are not completely effective and some of the oil invariably collects at various points in the system as it circulates with the refrigerant. This of course requires the use of some means to get the oil out of the system and back into the compressor in order to maintain the proper oil level in the crankcase. This problem is accentuated where a plurality of compressors are employed in series or in parallel, the primary difficulty being that of maintaining a common oil level in the crankcases of different compressors which may receive recirculating oil and lose it again at varying rates. Numerous schemes to overcome these oil handling problems have been tried. Thus oil sumps and drain lines have been provided to collect the oil which accumulates in the

refrigeration circuit and return it to the compressors; and flow lines have been connected between the crankcases of multiple compressors in an effort to maintain the oil therein at the desired level. However, none of these approaches has proven to be entirely satisfactory for reasons which are developed below.

With a view towards overcoming the aforesaid lubrication problems, I have invented an oil handling system particularly adapted to insure the proper lubrication of a plurality of compressors operating either in series to serve a multi-temperature cooling load or in parallel to handle the cooling load imposed on a single, large evaporator.

The basic concept and primary objective of my invention lies in the installation of an excess oil receiver in a multiple compressor refrigeration circuit in such a way as to provide a reservoir through which an excess of oil added to the system may circulate, the extra oil serving to refill the compressor crankcases as oil is gradually lost from the compressors and deposited throughout the circuit.

More specifically, an object of my invention is to provide an excess oil receiver in combination with a refrigeration circuit including a plurality of series connected reciprocating compressors operating at different pressure levels and having their crankcases connected by an oil flow line, the excess oil receiver being connected to the crankcase of the lowest pressure stage compressor at the point of normal oil level therein.

A second object is to provide excess oil receiver means in combination with a refrigeration system including a plurality of compressors operating in parallel, the excess oil receiver being connected to the crankcases of the receivers at the normal oil level therein.

Another object is to provide an excess oil receiver connected in a multiple compressor refrigeration circuit as stated in the preceding objectives wherein the refrigeration circuit also includes means to continuously recirculate oil from the excess oil receiver to the compressor crankcases.

A still further objective of my invention is to provide oil handling apparatus as stated in the aforesaid objectives wherein an ejector operated by the refrigerant gas flowing to the compressors and connected to the excess oil receiver serves as the means for recirculating oil from the excess oil receiver to the compressor crankcases.

These and other objects and advantages of my invention will be readily understood as the following description of my invention is read in conjunction with the accompanying drawings of which:

FIGURE 1 is a schematic view of a multiple stage refrigeration system incorporating my improved oil handling apparatus;

FIGURE 2 is a schematic view of a parallel compressor installation incorporating my improved oil handling apparatus; and

FIGURE 3 is a schematic illustration of an alternative form of oil receiver means for use in the system of FIGURE 2.

The refrigeration system of FIGURE 1 includes a relatively high temperature evaporator **2** which may handle an air conditioning load, and a low temperature evaporator **16** cooling, for example, an ice cream case. Air to be cooled is circulated over evaporator coil **2** by a fan **4** driven by motor **6**. A similar fan-motor combination **18–20** may also be provided for low temperature coil **16**. The outlet of low temperature coil **16** is connected via suction line **24** to the suction inlet of low stage compressor **13**. The discharge line **12** from compressor **13** is connected to a second, high pressure stage compressor **14**; and suction line **10** from high temperature evaporator **2** leads into line **12** at the inlet to compressor **14**. Thus the refrigerant in coil 2 evaporates at the relatively higher pressure prevailing in line 12 between the low and high stages of compression.

The refrigerant discharging from compressor 14 is conducted into an oil separator 28 by conduit 26. Conduit 32 leads from the top of separator 28 to condenser 34, the outlet of which discharges into liquid refrigerant receiver 36. Liquid line 38 connects receiver 36 with evaporator coils 2 and 16, the flow of refrigerant through these coils being regulated by thermostatic expansion valves 8 and 22 respectively.

The multiple stage refrigeration system described thus far is conventional, and operates in the normal manner to produce a low temperature refrigerating effect at evaporator 16 and a higher temperature cooling effect at evaporator 2. Refrigerant evaporating in coils 16 and 2 is returned to compressors 13 and 14 through suction lines 24 and 10 respectively, compressed and subsequently condensed to the liquid state in condenser 34. Liquid refrigerant accumulates in receiver 36 from which it is supplied to coils 2 and 16 through valves 8 and 22 for re-evaporation. A substantial portion of the oil pumped out of compressors 13 and 14 with the refrigerant is removed from admixture therewith in separator 28. As the oil level rises in accumulator 28, float valve 30 opens and permits the oil to return to the crankcase of high stage compressor 14 through pipe 40. Oil flow line 43 having capillary tube 42 therein connects the crankcases of compressors 13 and 14 at the point where it is desired to maintain the oil level in the crankcases. When the oil reaches the desired level in the crankcase of compressor 14, it overflows through capillary tube 42 into the crankcase of compressor 13, the higher pressure in the crankcase of high stage compressor 14 acting to force the oil through capillary tube 42. The pressure differential between the high and low stage compressor crankcases is thus maintained by capillary tube 42, which also functions to deliver the oil into the low stage compressor crankcase at a controlled rate. In lieu of capillary tube 42, a float valve responsive to the oil level in the crankcase of compressor 14 could be used to regulate the flow of oil into the crankcase of compressor 13.

As is well known in the refrigeration art, separator 28 is not fully effective to eliminate all of the oil entrained with the refrigerant. Thus some oil is continuously carried over into the refrigeration circuit where a portion of it is gradually deposited in piping traps, and as a film on the walls of the tubing. Evaporator coils 2 and 16 are of the direct expansion type, and the refrigerant velocity through these coils is normally great enough to sweep the oil out into suction lines 10 and 24. However, some oil will collect as a film on the walls of the coil tubing, and should the refrigerant velocity become abnormally low for some reason, a substantial amount of oil might accumulate in the evaporator coils. The oil that is carried all of the way through the refrigeration system with the refrigerant returns through suction lines 10 and 24 to compressors 13 and 14. Some of the oil separates from the refrigerant in the compressor bodies before the refrigerant enters the compressor suction valves, and a portion of the oil is entrained with the refrigerant discharging into separator 28. Since all of the oil that is carried over into the system with the refrigerant leaving separator 28 is not returned to the compressors through suction lines 10 and 24, and a portion thereof is gradually accumulated throughout the system, the oil level in the compressor crankcases will slowly drop. Furthermore, the levels in the two crankcases will quite likely drop unevenly as a result of several operating characteristics of the multiple stage compressor system I have shown. First of all, the loss of oil from the crankcases of compressors 13 and 14 may well take place at different rates due to differences in the degree of oil leakage around the compressor pistons and in the amount of foaming of the refrigerant-oil mixture in the crankcases. Secondly, the accumulation of any appreciable amount of oil in the refrigeration system would probably cause the oil level in the low stage compressor 13 to suffer the greatest drop because of the fact that the crankcase of this compressor will not receive any oil through capillary tube 42 until the oil in the crankcase of compressor 14 has risen to the predetermined operating level.

Thus not only must some means be incorporated in the system to insure that the oil level in compressors 13 and 14 does not drop to a harmfully low level, but also some means must be devised to maintain the oil level in the two crankcases at the same predetermined operating level. In order to compensate for the gradual loss of oil from the compressor crankcases, I propose to provide an initial excess of oil in the refrigeration system. Since the direction of oil flow from separator 28 through the crankcase of compressor 14 to the low stage compressor 13 through capillary tube 42 would soon cause the excess of oil to accumulate to an undesirably high level in the crankcase of compressor 13, some means must exist to handle the excess oil until it is needed. For this purpose, I have provided excess oil receiver 46 connected via pipe 44 to the crankcase of compressor 13 at the normal oil level therein. Thus, when the system is first put into operation, the excess oil will accumulate in receiver 46 rather than in the crankcase of compressor 13. In order to recirculate the excess oil from receiver 46 back through the compressors, an eductor tube 48 having a restrictor valve 50 therein is installed with one open end near the bottom of receiver 46 and the other end connected to venturi ejector 52 positioned in suction line 24.

My oil handling apparatus operates as follows. An excess of oil beyond that normally required for the proper lubrication of compressors 13 and 14 is provided in oil receiver 46, and the refrigeration system is started up. The flow of refrigerant gas from suction line 24 through eductor 52 will induce a slow flow of oil from receiver 46 through tube 48 back into compressor 13. Restrictor 50 in tube 48 meters the oil flow through suction line 24 at a rate which compressor 13 can handle. Some of this oil will fall into the crankcase of compressor 13 and the remainder will be carried through pipe 12 into compressor 14. That portion of the oil which does not drop into the crankcase of compressor 14 will flow into separator 28 with the refrigerant gas discharging through line 26. The action of float valve 30 will eventually permit the oil removed from the refrigerant stream by separator 28 to flow back into the crankcase of compressor 14 through pipe 40. Since compressor 14 will have all of the oil it needs when the system first begins to operate, the excess oil will flow through capillary tube 42 into the crankcase of compressor 13. The oil requirements for compressor 13 also being satisfied at this point, the excess oil will ultimately overflow through conduit 44 into receiver 46. There will thus be a continuous circulation of oil from receiver 46 through the crankcases of compressors 13 and 14, and as long as no appreciable amount of oil is lost from the crankcases, this excess oil will flow back into receiver 46 and be recirculated. Eventually, the operation of the refrigeration system will result in a substantial amount of oil being deposited in the condenser, evaporators, and associated piping as it is carried therethrough with the refrigerant gas leaving separator 28. This will cause an oil loss from the crankcases of compressors 13 and 14, which would quite likely be damaged if the oil were not replaced. Such an eventuality is avoided by my excess oil handling system. The excess oil being constantly recirculated from receiver 46 will quickly make up the oil deficiency in compressors 13 and 14 in order to bring the oil in the compressor crankcases back up to the normal operating level. There is therefore no danger of the compressors operating for any length of time with insufficient oil.

The application of my oil handling apparatus to a parallel compressor installation will now be described with reference to FIGURE 2, like reference numerals being used to identify like elements of FIGURE 1. Compressors **73** and **74** are connected by suction conduits **72** and **71** respectively to common suction line **70** leading from a single evaporator **62**. Discharge conduits **75** and **77** connect compressors **73** and **74** to a common discharge line **76**, which is shown emptying into oil separator **28**. Conduit **32** leads from oil separator **28** to condenser **34**, from which liquid refrigerant flows into receiver **36**. Liquid refrigerant is directed from receiver **36** to evaporator coil **62** by liquid line **38**, the flow of refrigerant through coil **62** being regulated by thermostatic expansion valve **68**. Fan **64**, driven by motor **66**, circulates air over coil **62**. Oil eliminated from the oil-refrigerant mixture discharging from compressors **73** and **74** into oil separator **28** is directed back to the compressor crankcases by pipe **80** and branch pipes **81** and **82** connected thereto. In some cases oil separator **28** is not used and the oil is permitted to circulate through the circuit with the refrigerant, suction conduits **71** and **72** being relied upon to return equal amounts of oil to the crankcases of both compressors. In any event, systems of this type invariably suffer from an unequal distribution of oil to the crankcases of the multiple compressors. Thus one of the crankcases will eventually be starved of oil, and as oil gradually accumulates throughout the system, this compressor oil shortage becomes more severe. My concept of putting an excess of oil in the system to begin with and providing receiver means through which this excess may circulate is equally effective to overcome these oil distribution problems on parallel compressor installations. To this end I provide separate excess oil containers **86** and **87** connected to the crankcases of compressors **73** and **74** at the normal oil level therein by oil pipes **84** and **83** respectively. Eductor tubes **96** and **94** having restrictors **90** and **91** therein connect oil containers **86** and **87** with suction line ejector **92** through common conduit **88**. Before the refrigeration system is started up, oil containers **86** and **87** are provided with an amount of oil in excess of that placed in the crankcases of compressors **73** and **74** for the proper lubrication thereof. When the system begins running, oil will be slowly educted from containers **86** and **87** by ejector **92** into common suction line **70**. Compressors **73** and **74** each receive a portion of the oil circulated from containers **86** and **87** by means of suction lines **72** and **71**. The oil that is carried over into separator **28** and recovered therein is returned to the compressor crankcases by pipes **81** and **82**. Since the crankcases of compressors **73** and **74** are initially provided with the amount of oil needed for proper lubrication, the oil returning to the compressors from containers **86** and **87** will raise the crankcase oil levels above that desired. This excess oil will overflow through pipes **83** and **84** into containers **86** and **87** and ultimately be recirculated through conduit **88** and common suction line **70**. This circulation of a small amount of excess oil through the compressor crankcases will continue as long as the system is in operation. The operation of the system over a prolonged period of time may eventually cause an unbalance in the crankcase oil levels as a result of unequal oil return to the separate compressors through suction lines **71** and **72** and oil pipes **81** and **82**. The compressor that is being starved of oil will likely suffer an even greater oil shortage as an appreciable amount of oil is subsequently deposited throughout the refrigeration circuit. If the oil unbalance is such that the oil in one crankcase rises above the normal operating level, the excess will overflow into the oil container **86** or **87** connected thereto and be redistributed to both crankcases through conduit **88** and common suction line **70**. Furthermore, a portion of the excess oil continuously circulating from oil containers **86** and **87** will be utilized to replenish the oil lost from the crankcase of the compressor being starved of oil. In this manner, my oil handling apparatus operates to maintain the oil levels in the several crankcases in balance and to compensate for an oil shortage before the working parts of either compressor can be damaged.

FIGURE 3 illustrates a variation of the arrangement shown in FIGURE 2 wherein a single excess oil container **85** is used in place of the two separate oil containers **86** and **87**. With this arrangement, oil pipes **83** and **84** leading from the crankcases of compressors **74** and **73** connect to the same container **85**. A single eductor tube, which is an extension of common conduit **88**, serves to withdraw oil from container **85**. The operation of the oil handling apparatus in conjunction with the refrigeration system is essentially the same as described above with respect to FIGURE 2. The use of a single oil container as shown in FIGURE 3 offers the advantage of a simpler and less expensive installation. However, such an installation is susceptible to an operating disadvantage if a pressure differential should develop between the crankcases of compressors **73** and **74**, which are intended to be at the same pressure level on a parallel compressor system. Such a pressure difference might occur as a result of different pressure losses in the suction and discharge lines connected to the two compressors. In this event, the higher pressure prevailing in the one crankcase would also exist at substantially the same level in the pipe **83** or **84** connected thereto, as well as in container **85**. This higher pressure could very well prevent or considerably inhibit the overflow of oil from the lower pressure crankcase through the other of the pipes **83** or **84** into container **85**. For this reason the double excess oil container arrangement of FIGURE 2, which is not susceptible to such a problem, is preferred.

Those skilled in the refrigeration art will readily appreciate that my oil handling apparatus as described above with respect to FIGURES 1 through 3 overcomes disadvantages associated with devices heretofore used to maintain a proper oil level in the crankcases of multiple compressors. Drain tubes conventionally employed to return oil to the compressors from evaporators and other places in the system where oil tends to accumulate are not entirely satisfactory for several reasons. In the first place, in the time that is required for such devices (see, for example, U.S. Patent No. 2,246,845 issued on June 24, 1941) to perform their intended function of returning lost oil to the compressors, a compressor operating with an insufficient amount of oil may be damaged. Moreover, oil tends to be deposited throughout the circuit, as was noted above, and there is thus no quick and convenient way to collect this oil and return it to the compressors. By connecting excess oil receiver means in a refrigeration circuit in the manner I have shown, I overcome these problems by providing a continuously circulating oil reserve which is immediately available to replace any oil lost from the compressor crankcases. Furthermore, the arrangements I have provided insure the maintenance of common oil levels in the crankcases of multiple compressors.

I do not intend that my invention should be limited to the particular embodiments shown and described, which are illustrative only. For instance, any number of compressor stages could be employed in FIGURE 1 depending upon the number and variety of cooling loads to be served. I also appreciate that pump means, such as a positive displacement pump could be utilized to circulate oil from the excess oil receivers of FIGURES 1, 2 and 3 to the compressors. It would also be possible to pump the oil from the excess oil receiver directly to oil separator **28** and thence to the compressor crankcases, rather than educting the excess oil from the receiver means into the compressor suction lines. It is contemplated that these and other variations which will occur to those skilled in the art will be within the spirit and scope of my invention as defined by the following claims.

I claim:

1. Refrigeration apparatus comprising: a plurality of compressors having oil carrying crankcases, said compressors being interconnected in series flow relationship with a condenser and evaporator means in a closed refrigeration circuit, said evaporator means comprising a low temperature evaporator and a high temperature evaporator, said plurality of compressors comprising a low pressure stage compressor and a high pressure stage compressor, and said refrigeration circuit including a first suction line leading from said low temperature evaporator to the suction inlet of said low pressure stage compressor and a second suction line leading from said high temperature evaporator to the suction inlet of said high pressure stage compressor; and oil handling apparatus for insuring the proper lubrication of said compressors, said oil handling apparatus comprising; oil receiver means containing an excess of oil beyond that initially provided in said crankcases of said compressors, first conduit means placing said oil receiver means in fluid flow communication with said crankcases at the normal oil level therein, second conduit means connecting said oil receiver means to a point in said refrigeration circuit, and pump means connected to said second conduit means for circulating oil from said oil receiver means back into said refrigeration circuit.

2. Refrigeration apparatus as recited in claim **1** wherein said oil receiver means comprises a single container and said first conduit means comprises a pipe connecting said container to the crankcase of said low pressure stage compressor and an oil flow line extending between the crankcases of said high and low pressure stage compressors.

3. Refrigeration apparatus as defined in claim **2** and further including a flow controller in said oil flow line.

4. Refrigeration apparatus as defined in claim **1** and further including an oil separator in said refrigeration circuit between the discharge port of said high pressure stage compressor and said condenser, said oil separator being connected by a pipe to the crankcase of said high pressure stage compressor.

5. Refrigeration apparatus comprising: a plurality of compressors having oil carrying crankcases, said compressors being interconnected with a condenser and evaporator means in a closed refrigeration circuit; and oil handling apparatus for insuring the proper lubrication of said compressors, said oil handling apparatus comprising; oil receiver means containing an excess of oil beyond that initially provided in the crankcases of said compressors, first conduit means placing said oil receiver means in fluid flow communication with the crankcases of said compressors at the normal oil level therein, second conduit means connecting said oil receiver means to a point in said refrigeration circuit, and pump means connected to said second conduit means for circulating oil from said oil receiver means back into said refrigeration circuit, said pump means comprising an ejector operated by refrigerant gas flowing from said evaporator means to said compressors.

6. Refrigeration apparatus comprising: a plurality of compressors having oil carrying crankcases, said compressors being interconnected in parallel flow relationship with a condenser and evaporator means in a closed refrigeration circuit, said refrigeration circuit including a common suction line leading from said evaporator means to said compressors and a common discharge line leading from said compressors to said condenser; and oil handling apparatus for insuring the proper lubrication of said compressors, said oil handling apparatus comprising; oil receiver means containing an excess of oil beyond that initially provided in said crankcases of said compressors, said oil receiver means comprising separate containers connected

by separate pipes to said crankcases of said compressors at the normal oil level therein, conduit means connecting said containers to a point in said refrigeration circuit, and pump means connected to said conduit means for circulating oil from said containers back into said refrigeration circuit.

7. Refrigeration apparatus comprising: a plurality of compressors having oil carrying crankcases, said compressors being interconnected in parallel flow relationship with a condenser and evaporator means in a closed refrigeration circuit, said refrigeration circuit including a common suction line leading from said evaporator means to said compressors and a common discharge line leading from said compressors to said condenser; and oil handling apparatus for insuring the proper lubrication of said compressors, said oil handling apparatus comprising; oil receiver means containing an excess of oil beyond that initially provided in said crankcases of said compressors, said oil receiver means comprising a single container connected by separate pipes to said crankcases of said compressors at the normal oil level therein, conduit means connecting said container to a point in said refrigeration circuit, and pump means connected to said conduit means for circulating oil from said container back into said refrigeration circuit.

8. Refrigeration apparatus as defined in claim **7** wherein said conduit means connects said container to said common suction line.

9. Refrigeration apparatus as defined in claim **7** wherein said pump means comprises an ejector operated by refrigerant gas returning through said common suction line to said compressors.

10. Refrigeration apparatus comprising: a plurality of compressors having oil carrying crankcases, said compressors being interconnected in parallel flow relationship with a condenser and evaporator means in a closed refrigeration circuit, said refrigeration circuit including a common suction line leading from said evaporator means to said compressors and a common discharge line leading from said compressors to said condenser; and oil handling apparatus for insuring the proper lubrication of said compressors, said oil handling apparatus comprising; oil receiver means containing an excess of oil beyond that initially provided in said crankcases of said compressors, first conduit means placing said oil receiver means in fluid flow communication with said crankcases of said compressors at the normal oil level therein and operative to permit the overflow of excess oil from said crankcases to said oil receiver means, second conduit means connecting said oil receiver means to a point in said refrigeration circuit, pump means connected to said second conduit means for circulating oil from said oil receiver means back into said refrigeration circuit, and an oil separator in said common discharge line, said oil separator being connected by pipes to said crankcases of said compressors.

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