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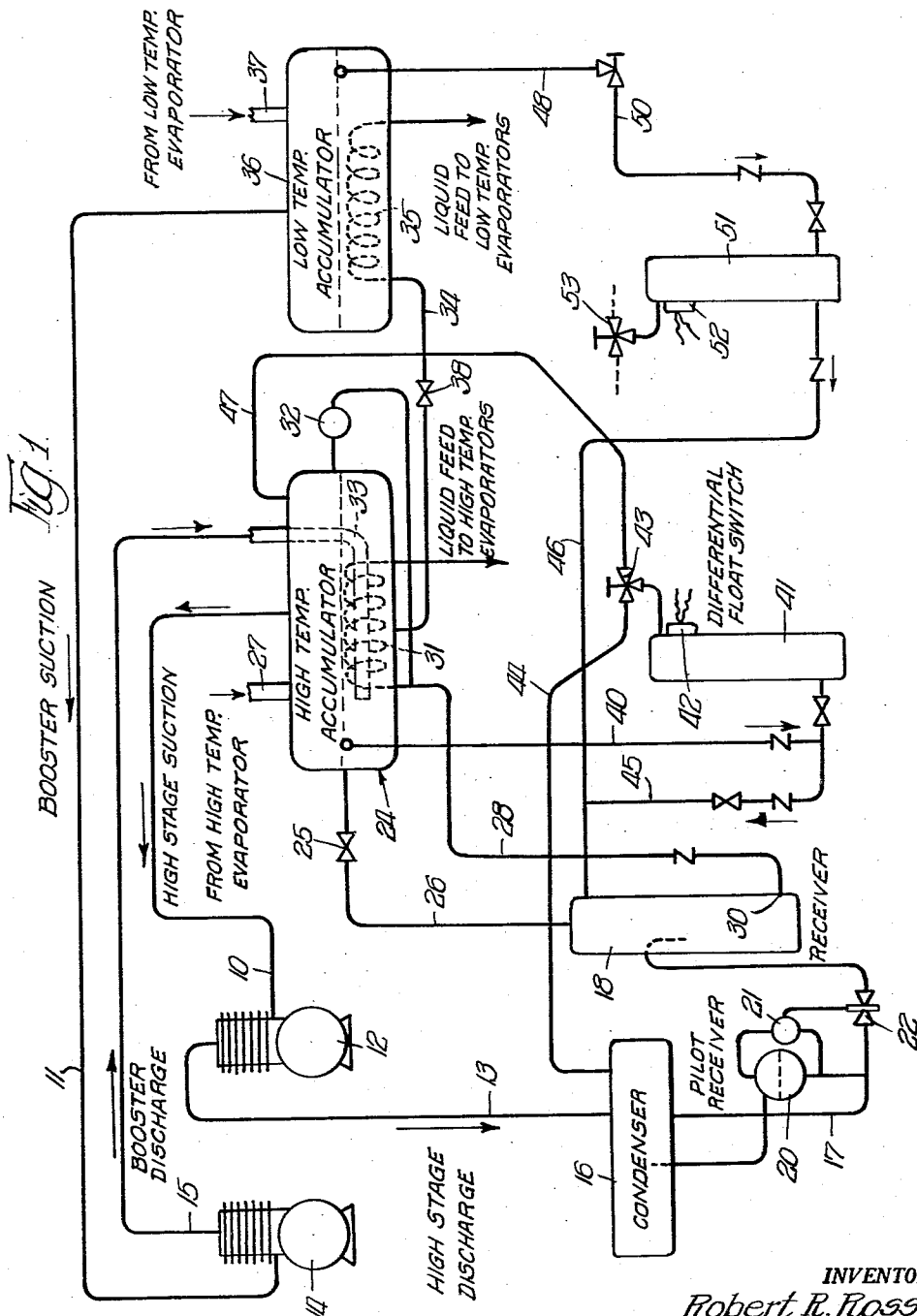
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2,966,043

BALANCED CIRCULATING SYSTEM FOR REFRIGERATION

Filed Aug. 17, 1959

4 Sheets-Sheet 1



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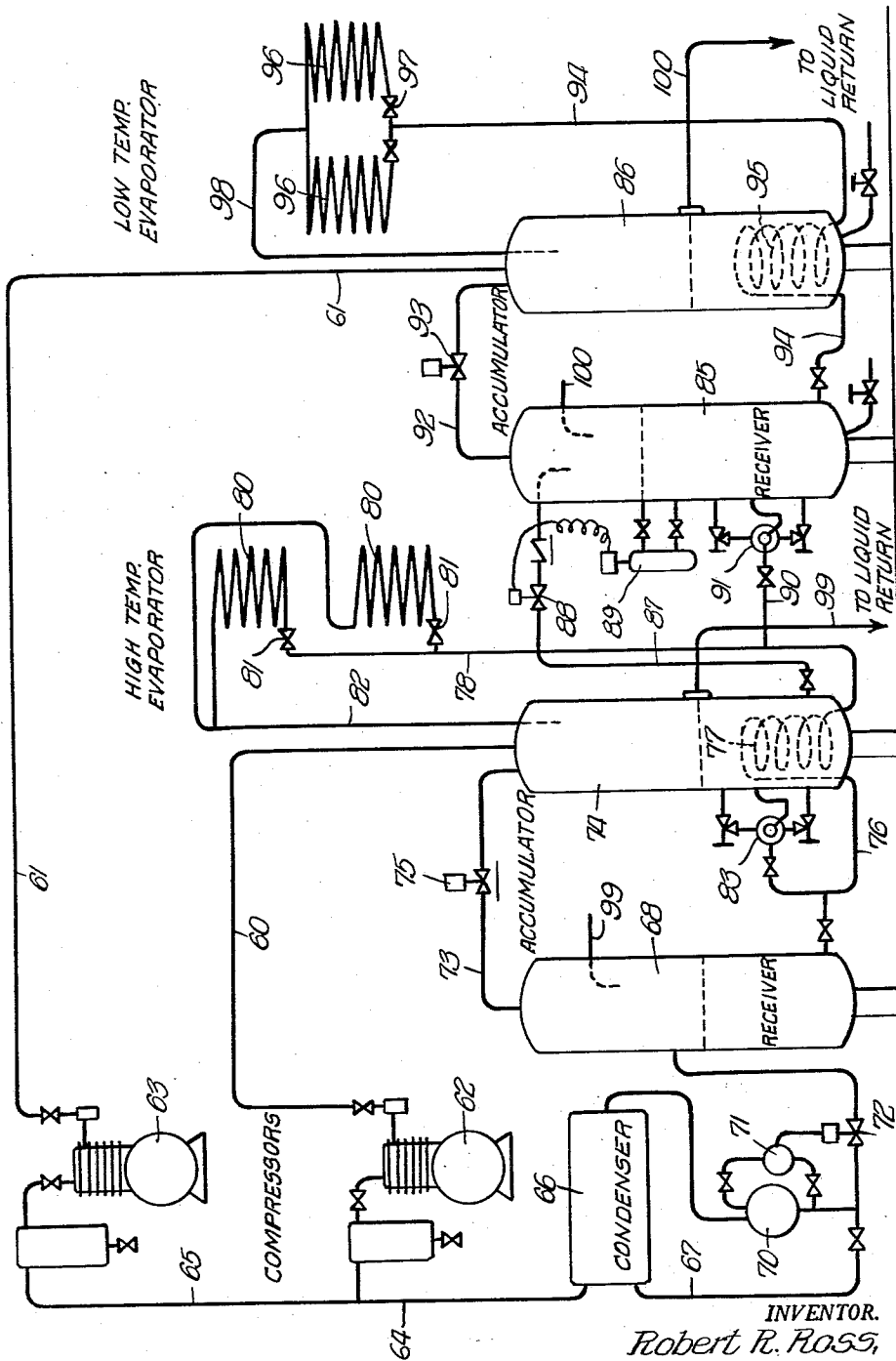
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Fig. 2



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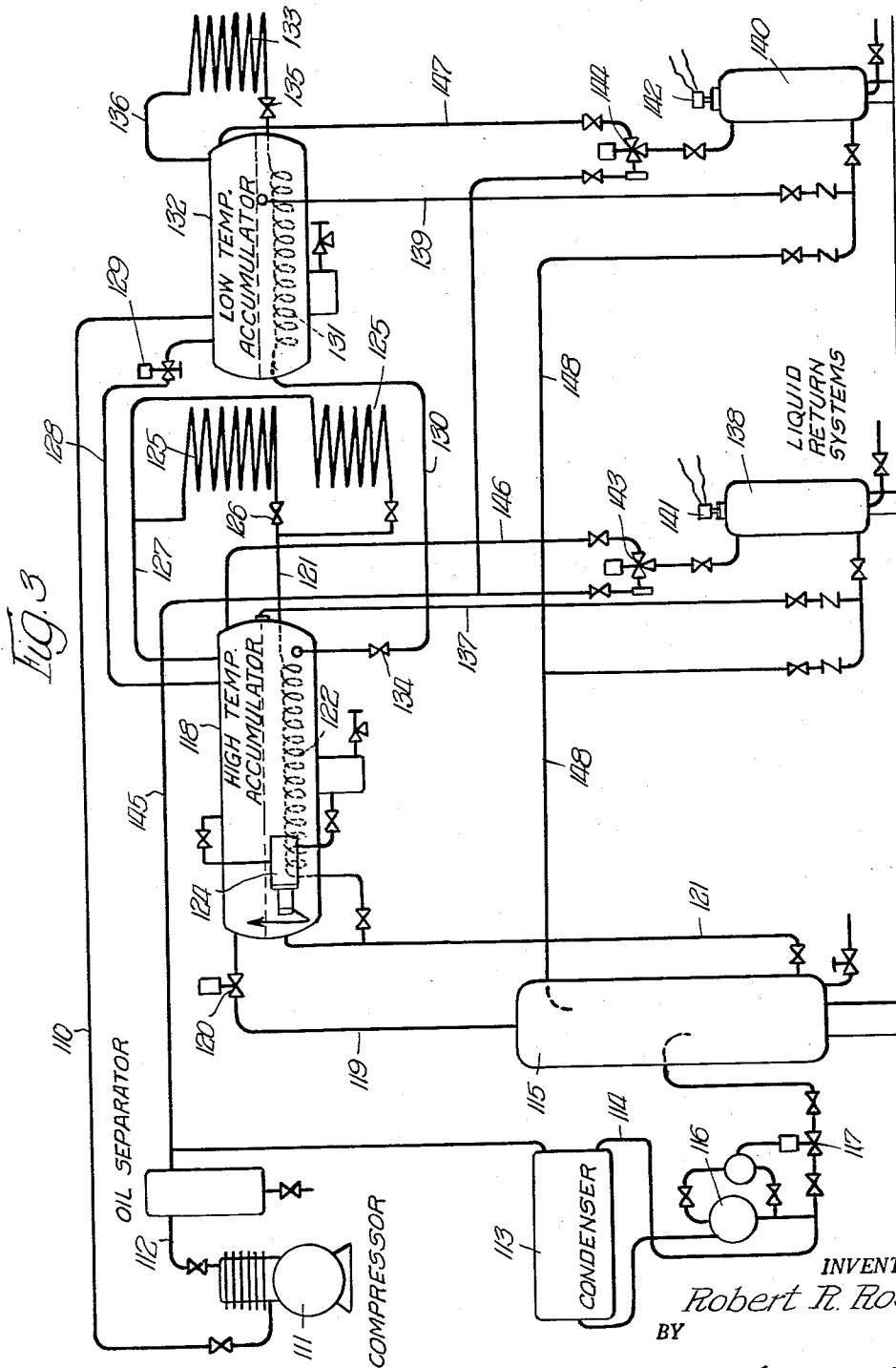
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4 Sheets-Sheet 3



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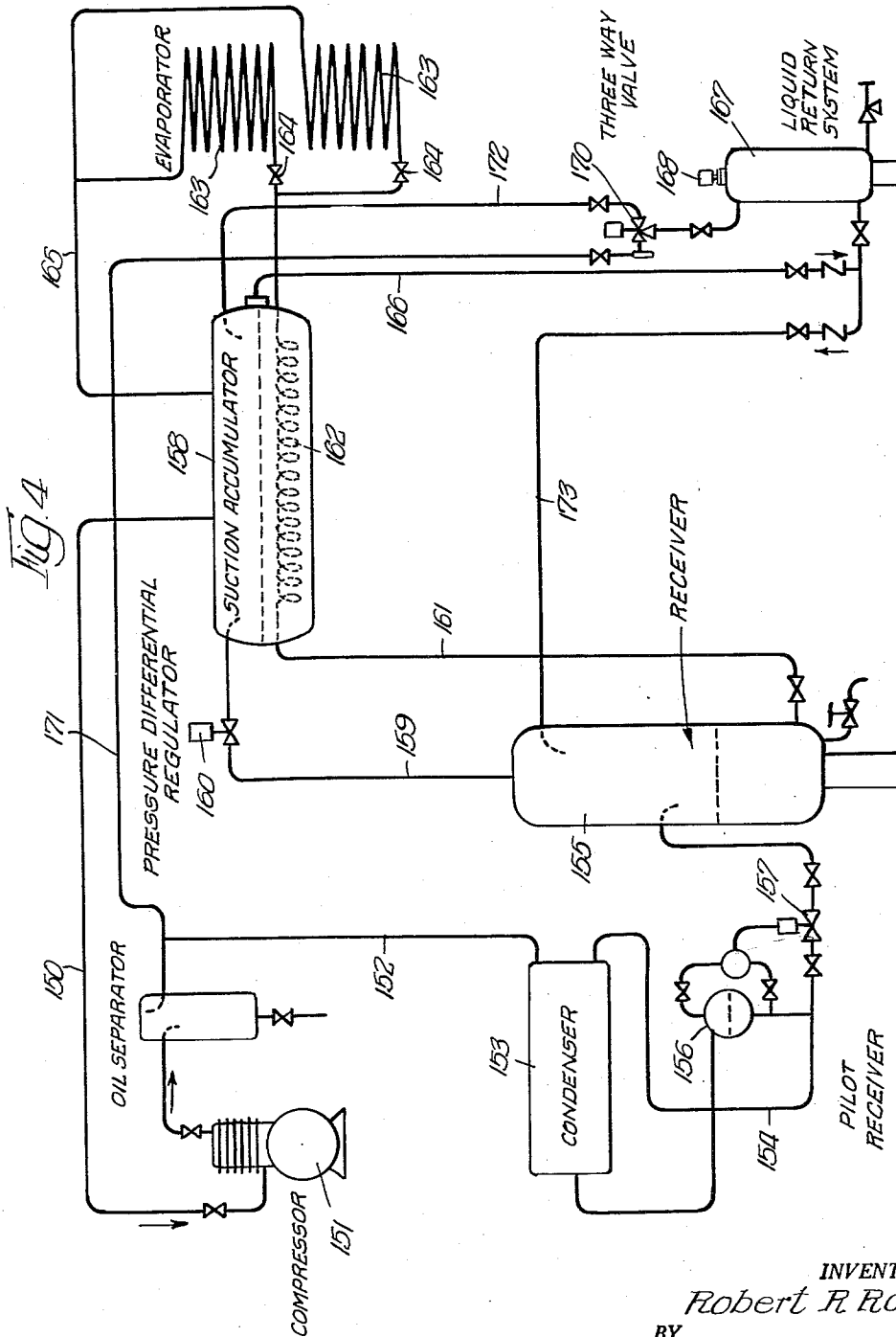
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BALANCED CIRCULATING SYSTEM FOR REFRIGERATION

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4 Sheets-Sheet 4



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2,966,043

BALANCED CIRCULATING SYSTEM FOR REFRIGERATION

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9 Claims. (Cl. 62—174)

The invention relates to refrigerating systems and has reference more particularly to large capacity industrial type refrigerating systems wherein it is necessary to protect the compressor of the system from liquid refrigerants such as would otherwise return in the suction line to the compressor.

The refrigerant circulating system of the invention is designed for incorporation in the refrigerating system of an industrial plant such as may operate with multi-stages of compression and with evaporators discharging to the high stage compressor suction as well as to the booster compressor suction. However, the system may also be applied to refrigeration plants using single stage operation with various suction pressures, provided there is sufficient pressure difference between the evaporators to effect the necessary flow requirements.

An object of the invention is to provide improvements in refrigerating systems, particularly of the industrial type, whereby complete and constant circulation of both the liquid and the gaseous refrigerant is accomplished without adding to the power requirements of the plant.

Another object is to provide improved apparatus for the circulation of the liquid refrigerant in a controlled manner and which will be caused to by-pass the compressor of the system so that the evaporators can be operated continuously and in a flooded condition.

Another object of the invention resides in the provision of a refrigerant circulating system of the type as described, having a constant pressure differential for feeding liquid refrigerant to a plurality of evaporators operating at different suction pressures.

A more specific object is to provide a refrigerant circulating system incorporating the improvements as described and wherein the required pressure differential is produced by using the pressure of the available gas in the system, thus eliminating the need for additional mechanical pumps.

Another specific object of the invention is to provide a system of circulating a refrigerant and which will use the excess liquid refrigerant returning from the evaporators at the high suction pressure level to feed the evaporators at the low suction pressure level.

A further object is to provide a refrigerant circulating system which will use the liquid returning from the high temperature evaporators to sub-cool the liquid fed to these evaporators and which will also use the liquid from the low temperature evaporators to sub-cool the liquid fed to the said low temperature evaporators.

Other objects and advantages of this invention will be apparent from the following description and the accompanying drawings wherein—

Figure 1 is a diagrammatic view illustrating a refrigerating system having incorporated therein high and low temperature evaporators with two compressors, the same comprising the improved combination of the invention.

Figure 2 is a diagrammatic view of a modified refrigeration system basically similar to Figure 1 but incorporating two separate liquid receivers.

Figure 3 is a diagrammatic view illustrating another modified refrigerating system coming within the invention, the same combining high and low evaporators with one stage of compression, and

Figure 4 is a diagrammatic view showing a further modified form of the invention and comprising a single compressor-evaporator system.

Referring to Figure 1 of the drawings, the numeral 10 indicates a high stage suction line and the numeral 11 the booster suction line for returning the evaporated refrigerant from the high temperature evaporators and from the low temperature evaporators respectively. The drawings show the refrigerant feeding line to the said evaporators and the structure for effecting operation of the evaporators according to the invention will now be described in detail.

From the suction line 10, the returning refrigerant is delivered to the main compressor 12, having the high pressure discharge line 13. Also, for the suction line 11, the returning evaporated refrigerant is delivered to the booster compressor 14 having the high pressure discharge line 15. Both compressors are conventional in construction and in operation, being suitably driven so that the low pressure gas from the suction lines is increased in pressure and which results in a corresponding increase in temperature. The high pressure discharge line 13 delivers into the condenser 16, having an outlet connection 17 leading to the receiver 18. The condenser also has associated therewith a pilot receiver 20 and with which is combined the high side float valve 21 and the pilot operated control valve 22, the said pilot valve being interposed in the connection 17 leading to the receiver 18.

A considerable pressure difference exists between the condenser 16 and the receiver 18. Whereas the pressure within the condenser may approximate 160 pounds per square inch, which is about the same as the discharge pressure of the compressor 12, a reduced pressure will exist in the receiver and which may range from about 60 to 80 pounds per square inch. Also, a pressure difference exists between the receiver 18 and the high temperature, suction line accumulator 24. The receiver is maintained at a pressure which is higher than the intermediate pressure of the two stages by means of the pressure differential regulator 25 interposed in the connection line 26. The regulator will bleed the flash gas, which is evolved due to a decrease from the condenser pressure to receiver pressure, to the accumulator 24 at a controlled rate, thus maintaining a pressure of about 40 pounds per square inch in the accumulator, provided the regulator is set for 30 pounds and with a receiver pressure of about 70 pounds. If the accumulator pressure should rise to 50 pounds, then the pressure in the receiver will increase to approximately 80 pounds. It is understood that the pressure difference will be adjusted to the minimum required level to allow adequate flow through the feed line from the receiver 18 to all of the high temperature evaporators. The said accumulator receives the evaporated refrigerant gas from the high temperature evaporators through the suction line connection 27 and the accumulator will also receive any liquid refrigerant which may accompany the gas, the same being termed the "slop-over" and which must by-pass the compressor. The liquid which evaporates in the accumulator 24 due to the addition of heat from the subcooling coil 31, and from the heat gain in desuperheating the gas from line 33, is returned by suction line 10 to the compressor 12.

The liquid refrigerant feed line 28 to the high temperature evaporators connects with the receiver at 30 and said

line includes a cooling coil 31 located within the accumulator 24 and disposed below the level of the liquid refrigerant within the accumulator. From the coil the liquid refrigerant is fed to the high temperature evaporators. In case the amount of liquid returning to the accumulator from the high temperature evaporators is insufficient in quantity to satisfy the requirements of the low temperature evaporators, the low level controller 32 will supply the additional quantity as needed from the line 28. The accumulator 24 is also supplied with gaseous refrigerant from the discharge line 15 of the booster compressor, the said high pressure gas being supplied to the open-end conduit 33 which is submerged in the liquid refrigerant within the accumulator and thus said gas is cooled and condensed to the liquid form.

It will be understood that the pressure of the liquid in the intercooler 24 will be higher than the suction pressure from the low temperature evaporators. Thus, the liquid refrigerant from accumulator 24 will be supplied by line 34 to a cooling coil 35 located within the low temperature accumulator 36. From said coil, the liquid refrigerant is fed to the low temperature evaporators as indicated. Coil 35 is submerged in liquid refrigerant within the accumulator 36. The evaporated refrigerant gas from the low temperature evaporators together with any liquid refrigerant accompanying the gas is supplied to the accumulator by the suction line connection 37. Said liquid upon evaporating due to the heat gain from the subcooling coil 35, is then returned to the booster compressor by line 11. Since the accumulator 24 is acting as a receiver for the low temperature evaporators, it is necessary to provide a valve such as 38 in the outlet line 34.

The transfer of the liquid refrigerant from the accumulators 24 and 36 to the receiver is accomplished by a return system of the type disclosed and claimed in the Phillips patent, 2,589,859, granted March 18, 1952, and entitled Suction Line Liquid Return Trap. Liquid refrigerant flows by gravity from accumulator 24 by means of the line 40, the said line connecting with the accumulator at a location which will maintain the desired liquid level in the accumulator. Line 40 connects with the trap 41. When liquid in the trap reaches a pre-determined high level, the differential float switch 42 will actuate the three-way valve 43 to connect the top of the trap to the condenser 16 by means of the line 44. The high pressure gas from the condenser will force the liquid within the trap into the receiver 18 through the connecting lines 45 and 46. When the liquid refrigerant in the trap reaches a pre-determined low limit, the switch 42 will again actuate the three-way valve 43 to close the line 44 and connect the trap with line 47 leading to the accumulator 24. With the accumulator and trap thus equalized in pressure, the liquid refrigerant will again flow by gravity to the trap. The low temperature accumulator 36 is similarly connected by lines 48 and 50 to a trap 51 having a differential float switch 52 and a three-way valve 53. The structure operates in a manner exactly similar to that as described for trap 41. Accordingly, the liquid from the accumulators is transferred to receiver 18 by using the high pressure gas from the condenser. Also, the circulating system of Figure 1 employs the liquid refrigerant returning from the evaporators to sub-cool the liquid being fed to these evaporators. In addition a constant pressure differential is maintained for feeding the liquid refrigerant to the evaporators although the same operate at different suction pressures.

The circulating system of Figure 2 is similar in its basic aspects to that shown in Figure 1, with the exception that two separate liquid receivers are employed. The suction line 60 and the booster suction line 61 connect respectively with the main compressor 62 and the booster or lower suction pressure compressor 63. The high pressure discharge line 64 for the main compressor has connection with the discharge line 65 for the booster compressor and the same in turn deliver to the condenser 66. The

outlet for the condenser 66 is indicated by numeral 67 and the same leads to the high temperature receiver 68. The liquid refrigerant flow to the receiver is controlled by the pilot receiver 70 having combined therewith the high side float valve 71 and the pilot operated valve 72. The receiver 68 has connection at its top through the line 73 with the high temperature suction accumulator 74. The pressure differential regulator 75 maintains the desired pressure difference between the receiver and its accumulator. The liquid refrigerant from the receiver 68 is supplied by line 76 to the coil 77 which is submerged by the liquid refrigerant contained within the high temperature suction accumulator 74. From the coil 77 the liquid refrigerant feed line 78 delivers the refrigerant to the high temperature evaporators which may consist of two or more coils 80 connected in parallel and each having an expansion valve 81. The evaporated gas from the evaporators 80 together with liquid refrigerant entrained by the gas is returned to the accumulator 74 by the suction line connection 82. Referring again to line 76, it will be noted that a float valve 83 is interposed in said line together with certain hand operated valves for maintaining the desired liquid level within the accumulator 74 in those instances when the high temperature evaporators do not provide enough liquid to supply the low temperature evaporators.

The second stage of the apparatus of Figure 2 includes a low temperature receiver 85 and a low temperature accumulator 86. The line 87 connects with the accumulator 74 at its base and said line delivers liquid refrigerant to the receiver 85 adjacent the upper end of the receiver. The solenoid operated valve 88 is located in the line 87 adjacent receiver 85. The float switch 89 controls the solenoid of the valve 88 and thus controls the discharge of liquid refrigerant to the low temperature receiver. The float switch 89 therefore maintains a normal liquid level within the receiver. A second connection for the receiver 85 is provided by the line 90 which is tapped to the liquid line 78 and which has the float valve 91 interposed therein. Said float valve maintains a desired liquid level within the low temperature receiver 85 when the high temperature accumulator 74 and the low temperature accumulator 86 are at the same pressure.

The receiver 85 and the accumulator 86 are connected by the line 92 having the pressure differential regulator 93. As previously described, the regulator 93 bleeds the gas from the receiver 85 to the accumulator 86 in a controlled manner and thus maintains the desired lower pressure in the accumulator. The refrigerant feed line 94 supplies liquid from the receiver 85 to the coil 95 and the same connects with the low temperature evaporators 96. The coil is submerged in the liquid within the accumulator for sub-cooling. The evaporators have the expansion valves 97 and said evaporators deliver the evaporated gas and any liquid refrigerant entrained therein through the line 98 to the low temperature accumulator 86. The suction line 61 completes the system since the evaporated gas from the accumulator 86 is returned by said line to the compressor 63. For returning the liquid refrigerant to the respective receivers and in a manner to by-pass the compressors, the apparatus employs the return system of Figure 1, including the trap and three-way valve, all as described. Accordingly, the lines 99 and 100 for the high and low stages respectively are included in the said return system.

Figure 3 illustrates a balanced single stage circulating system providing two suction pressures. The suction line 110 has connection with the compressor 111 and the high pressure discharge line 112 from said compressor connects with the condenser 113. The outlet line 114 from the condenser leads to the receiver 115 and said line has interposed therein the pilot receiver 116 and the pilot operated float valve 117 for maintaining the desired liquid level within the receiver. The gas from the receiver 115 is passed in a controlled manner to the high temperature

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accumulator 118 by the line 119 having the pressure differential regulator 120. The liquid from the receiver is delivered by line 121 to the cooling coil 122 submerged within the liquid in the accumulator. Said accumulator 118 in this modification of the invention is provided with a float valve 124 which maintains a minimum level of liquid refrigerant within the accumulator when the high temperature evaporators are not in operation. The valve is of the normally closed type. From the coil 122 the liquid refrigerant line 121 leads to the high temperature evaporators 125. Said evaporators are provided with the expansion valves 126 and their suction line 127 returns the evaporated gas and entrained liquid to the accumulator 118.

The liquid from the accumulator 118 is delivered by line 130 to the coil 131 located within the low temperature accumulator 132. The coil 131 is submerged within the liquid in the low temperature accumulator for sub-cooling and said coil is in turn connected to the low temperature evaporator 133. The accumulator 118 acts as a receiver for the low temperature evaporator and according to the line 130 must be provided with the valve 134. The expansion valve 135 controls the feed of the liquid refrigerant to the evaporator 133 and the evaporated gas together with any entrained liquid is returned by the suction line connection 136 to the accumulator 132. The line 128 connects the accumulators 118 and 132 and said line is provided with the differential pressure regulator 129. The intermediate pressure thus maintained in 118 is adequate to feed all the low temperature evaporators.

The apparatus of Figure 3 incorporates liquid return systems basically similar to that as described for Figure 1. For example, liquid refrigerant will drain by gravity from accumulator 118 by means of the line 137 to the trap 138. In a similar manner, liquid refrigerant from accumulator 132 will drain by gravity through the line 139 to the trap 140. Both traps are equipped with differential float switches such as 141 and 142 and by means of the three-way valves 143 and 144 it is possible to alternately connect the traps to the high pressure discharge line 112 for evacuating the traps and to the respective accumulators 118 and 132 for venting the traps. Line 145 functions to connect the traps to the high pressure discharge line 112 whereas line 146 and 147 will function to connect the traps to their respective accumulator. When the traps are evacuated the liquid refrigerant is delivered by line 148 to the receiver 115.

The apparatus of Figure 4 consists of a balanced circulating system wherein a single stage is employed, the same having a single suction pressure. The suction line 150 connects with the compressor 151. The high pressure discharge line 152 leads to the condenser 153 and the liquid from the condenser is delivered by line 154 to a receiver 155. Said line 154 has interposed therein the pilot operated valve 157 which maintains the desired liquid seal in the pilot receiver 156. The gas from receiver 155 is delivered in a controlled manner to the suction accumulator 158 by the line 159 having the pressure differential regulator 160. The liquid refrigerant from the receiver 155 is delivered by line 161 to the coil 162. In accordance with the invention, the coil 162 is submerged within the liquid refrigerant contained within the accumulator 158. From the coil 162 the liquid refrigerant feed line 161 leads to the evaporator 163. Said evaporator may consist of one or more coils in parallel arrangement each having an expansion valve 164 and each connecting by means of the suction line 165 to the accumulator 158. The system is completed by the suction line 150 which delivers the evaporated gas from the accumulator to the compressor.

The apparatus of Figure 4 employs the liquid return system as herein described for returning the liquid refrigerant from the accumulator to the receiver and in a

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manner to by-pass the compressor. Accordingly, line 166 will drain liquid refrigerant from the accumulator by gravity and deliver the same to the trap 167. The trap in turn is provided with the differential float switch 168 and with a three-way valve 170. Actuation of the valve is controlled by the float switch for alternately connecting the trap to the high pressure discharge line 152 and to the accumulator 158 whereby the trap can be alternately evacuated and vented. Line 171 connects the three-way valve with line 152 whereas the valve is connected by line 172 with accumulator 158. When the trap 167 is evacuated, its charge of liquid refrigerant is delivered by line 173 to the receiver 155.

The invention is not to be limited to or by details of construction of the particular embodiment thereof illustrated in the drawings, as various forms of the device will of course be apparent to those skilled in the art without departing from the spirit of the invention or the scope of the claims.

What is claimed is:

1. In a refrigerating system, in combination, an evaporator, a feed line for supplying refrigerant under pressure to said evaporator in an amount greater than the evaporator is capable of evaporating, a suction line for drawing off the vaporized and liquid refrigerant from the evaporator, an accumulator in the suction line for trapping the liquid passing through the evaporator, said feed line including a coil having location within the accumulator and below the level of the liquid refrigerant within the accumulator for cooling the refrigerant flowing in the feed line in advance of supplying the refrigerant to the evaporator, and liquid return means including a reservoir for receiving and temporarily storing the excess liquid trapped in said accumulator, a conduit connecting said reservoir with the feed line in advance of the coil, means operable in response to changes in the level of the liquid in the reservoir, and valve means controlled by said level responsive means for introducing vaporized refrigerant from the pressure side of the system into said reservoir to force the liquid from the reservoir and into the said conduit for eventual delivery to the feed line.

2. A refrigerating system as defined by claim 1, additionally including a second evaporator and a second accumulator, the second accumulator being located in the suction line of the said second evaporator for trapping any liquid passing through the second evaporator, a feed line for the second evaporator and having connection with the first mentioned accumulator for feeding liquid refrigerant trapped by the first mentioned accumulator to the second evaporator, said feed line for the second evaporator including a coil located in the second accumulator below the level of the liquid refrigerant within the accumulator for cooling the refrigerant flowing in the feed line in advance of feeding the same to the second evaporator, and liquid return means for returning the excess liquid refrigerant from the second accumulator to the first mentioned feed line.

3. In a refrigerating system, in combination, an evaporator, a refrigerant feed line connecting with the evaporator and including a compressor, a condenser and a receiver, a suction line for returning evaporated gas from the evaporator to the compressor, an accumulator in the suction line for trapping any liquid refrigerant returning with the gas, a coil in the feed line and located in the accumulator below the level of the liquid refrigerant in the accumulator for cooling the refrigerant flowing in the line in advance of supplying the same to the evaporator, conduit means connecting the receiver with the accumulator, said means including a differential pressure regulator for controlling flow of the refrigerant gas from the receiver to the accumulator in a controlled manner, whereby the receiver is maintained at a pressure below condenser pressure but above evaporator pressure, a second evaporator and a second accumulator, a suction line for

the second evaporator and having the second accumulator interposed in the line for trapping any liquid refrigerant passing through the second evaporator, a second refrigerant feed line connecting the first mentioned accumulator with the second evaporator for feeding liquid refrigerant trapped by the first mentioned accumulator thereto, the second feed line having a coil located in the second accumulator below the level of the liquid refrigerant within the accumulator for cooling the refrigerant flowing in the line in advance of feeding the same to the second evaporator, and liquid return means associated with the accumulators respectively for returning the excess liquid from the accumulators to the receiver.

4. In a refrigerating system, in combination, a compressor, a condenser, an evaporator and a receiver, said receiver supplying liquid refrigerant under pressure to said evaporator in an amount greater than the evaporator is capable of evaporating, a suction line for drawing off the vaporized and liquid refrigerant from the evaporator, an accumulator in said suction line for trapping the liquid passing through the evaporator, a liquid feed line connecting the receiver with the evaporator, a coil in the feed line located within the accumulator and submerged in the liquid trapped by the accumulator for cooling the liquid refrigerant flowing in the line in advance of delivering it to the evaporator, means connecting the receiver with the accumulator, said means including a differential pressure regulator for maintaining a pressure in the receiver below condenser pressure and above evaporator pressure, and liquid refrigerant return means for draining the excess liquid from the accumulator and for returning the same to the receiver so as to by-pass the compressor of the system.

5. In a refrigerating system, in combination, a high temperature evaporator, a refrigerant feed line connecting with said evaporator and including a compressor, a condenser and a receiver, a suction line for returning evaporated gas from the evaporator to the compressor, an accumulator in the suction line for trapping any liquid refrigerant returning with the gas, a coil in the feed line and located in the accumulator below the level of the liquid refrigerant in the accumulator for cooling the refrigerant flowing in the line in advance of supplying the same to the evaporator, means connecting the receiver with the accumulator, said means including a differential pressure regulator for maintaining a pressure in the receiver below condenser pressure but above evaporator pressure, a low temperature evaporator, a second accumulator in the suction line from the low temperature evaporator for trapping liquid refrigerant returning in said line, a second feed line connecting the first mentioned accumulator with the low temperature evaporator for supplying the liquid refrigerant from within the accumulator to the said evaporator, and said second feed line including a coil having location within the second accumulator below the level of the liquid refrigerant therein for cooling the refrigerant flowing in the second feed line in advance of supplying the refrigerant to the low temperature evaporator.

6. A refrigerating system as defined by claim 5, additionally including liquid refrigerant return means for the first mentioned accumulator and for the second accumulator respectively, each said means draining the excess liquid from its accumulator and returning the same to the receiver.

7. In a refrigerating system, in combination, a high temperature evaporator, an accumulator connected to the suction line of said evaporator, a refrigerant feed line connecting with the evaporator and including a compressor, a condenser and a receiver, a coil in the feed line and located in the accumulator below the level of the

liquid refrigerant in the accumulator for cooling the refrigerant flowing in the feed line in advance of supplying the same to the evaporator, conduit means connecting the receiver with the accumulator, said means including a differential pressure regulator for controlling flow of the refrigerant gas from the receiver to the accumulator in a controlled manner, whereby the receiver is maintained at a pressure below condenser pressure but above evaporator pressure, a low temperature evaporator, a second accumulator connected to the suction line of the low temperature evaporator, a second refrigerant feed line connecting the first mentioned accumulator with the low temperature evaporator for feeding liquid refrigerant from the first mentioned accumulator to the said evaporator, a coil in the second feed line and located in the second accumulator below the level of the liquid refrigerant therein for cooling the refrigerant flowing in the line in advance of feeding the same to the low temperature evaporator, second conduit means joining the first mentioned accumulator with the second accumulator, said means including a differential pressure regulator for controlling flow of the evaporated refrigerant from the first mentioned accumulator to the second accumulator, whereby the first mentioned accumulator is maintained at a pressure below receiver pressure but above that of the low temperature evaporator, and a suction line connecting the second accumulator with the compressor.

8. A refrigerating system as defined by claim 7, additionally including liquid refrigerant return means for the first mentioned accumulator and for the second accumulator respectively, each said means returning the excess liquid refrigerant from the accumulators to the receiver.

9. In a refrigerating system, in combination, a high temperature evaporator, a first accumulator connected to the suction line of said evaporator, a refrigerant feed line connecting with the evaporator and including a compressor, a condenser and a first receiver, a coil in the feed line and located in the accumulator below the level of the liquid refrigerant in the accumulator for cooling the refrigerant flowing in the feed line in advance of supplying the same to the evaporator, conduit means connecting the first receiver with the first accumulator, said means including a differential pressure regulator for controlling flow of the refrigerant gas from the receiver to the accumulator in a controlled manner, whereby the receiver is maintained at a pressure below condenser pressure but above the pressure of the high temperature evaporator, a low temperature evaporator, a second receiver, a second accumulator connected to the suction line of said low temperature evaporator, a second refrigerant feed line connecting the first accumulator with the low temperature evaporator for feeding liquid refrigerant from the accumulator to said evaporator, said second feed line including the said second receiver and a second coil, said coil having a location within the second accumulator below the level of the liquid refrigerant therein for cooling the refrigerant flowing in the feed line in advance of supplying the same to the low temperature evaporators, conduit means connecting the second receiver with the second accumulator, said means including a differential pressure regulator for controlling flow of the refrigerant gas from the receiver to the accumulator, whereby the second receiver is maintained at a pressure below condenser pressure but above the pressure of the low temperature evaporator, and liquid return means for returning the excess liquid refrigerant from the accumulators to the receivers respectively.

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