Aug. 9, 1955 H. J. SCULLEN 2,714,806

REFRIGERATING SYSTEM

Filed Dec. 12, 1951 2 Sheets-Sheet 1

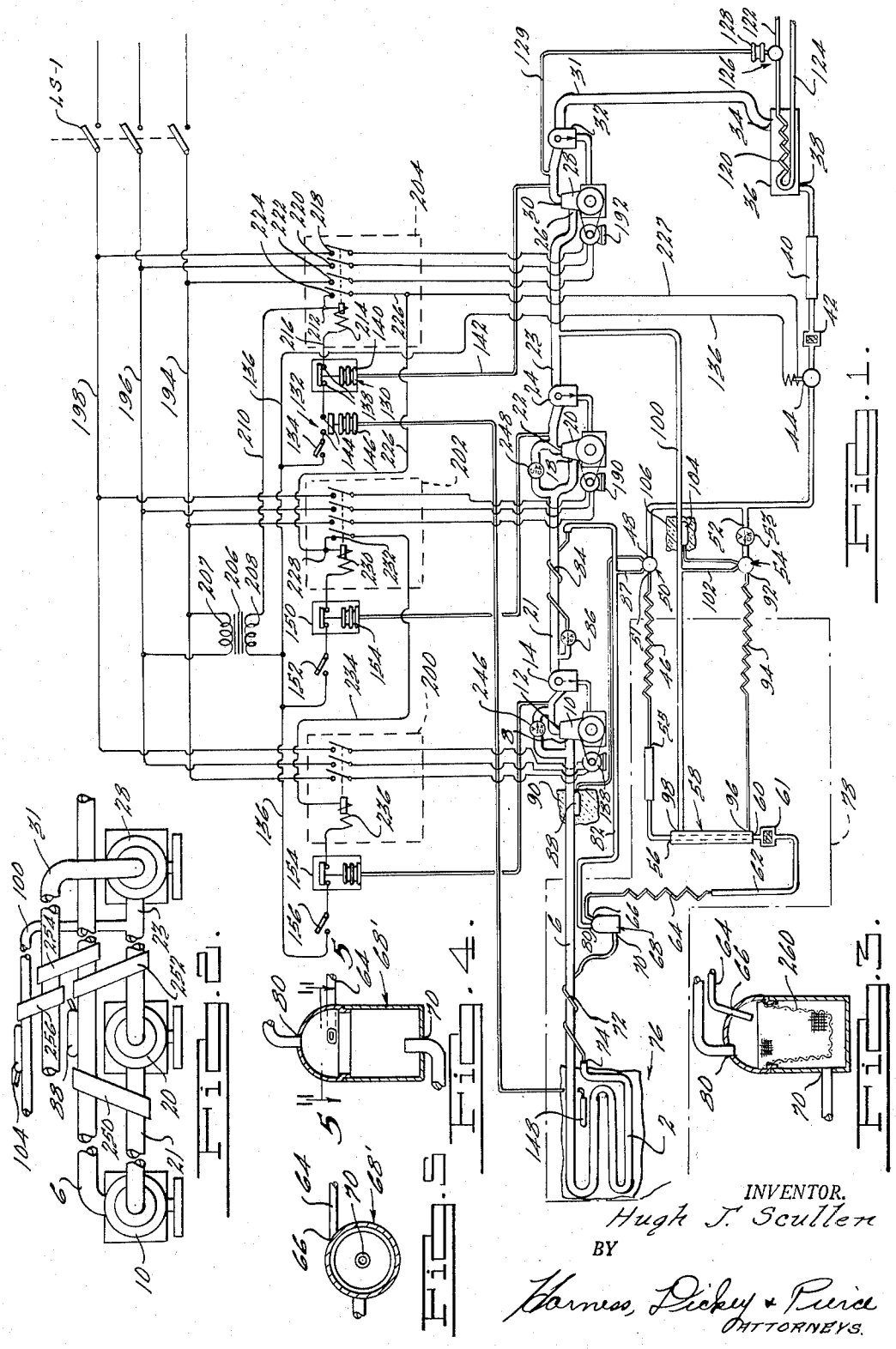

Fig. 1.

Fig. 2.

Fig. 4.

Fig. 5.

Fig. 3.

INVENTOR.
Hugh J. Scullen
BY
Harness, Dickey & Pierce
ATTORNEYS.

Aug. 9, 1955 H. J. SCULLEN 2,714,806

REFRIGERATING SYSTEM

Filed Dec. 12, 1951 2 Sheets-Sheet 2

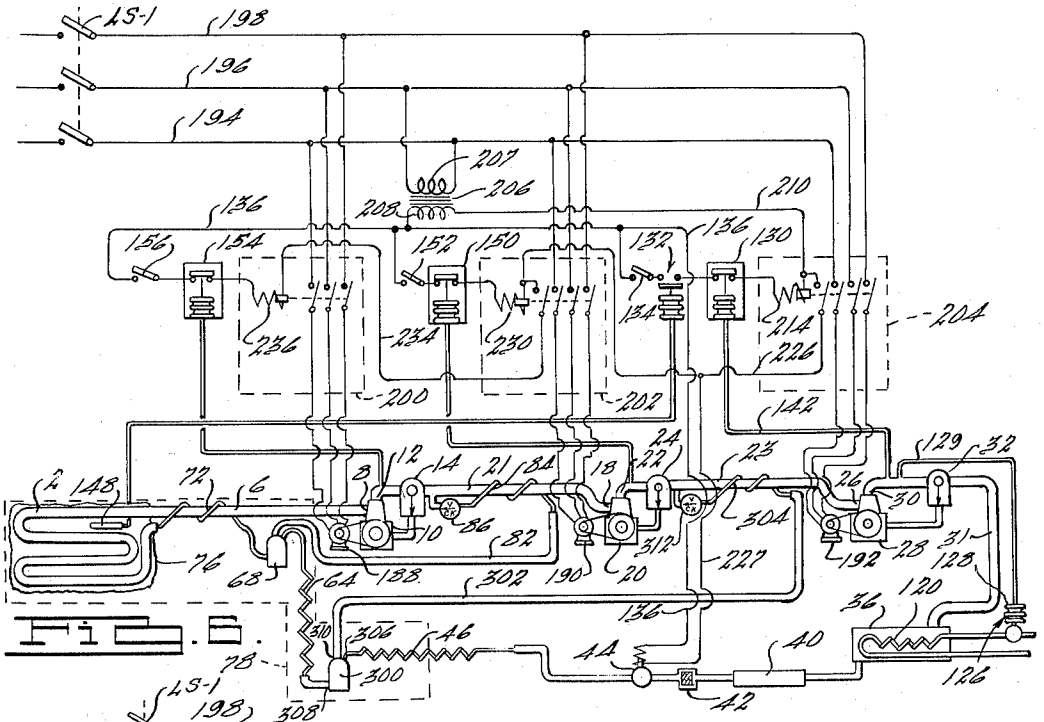

Fig. 6.

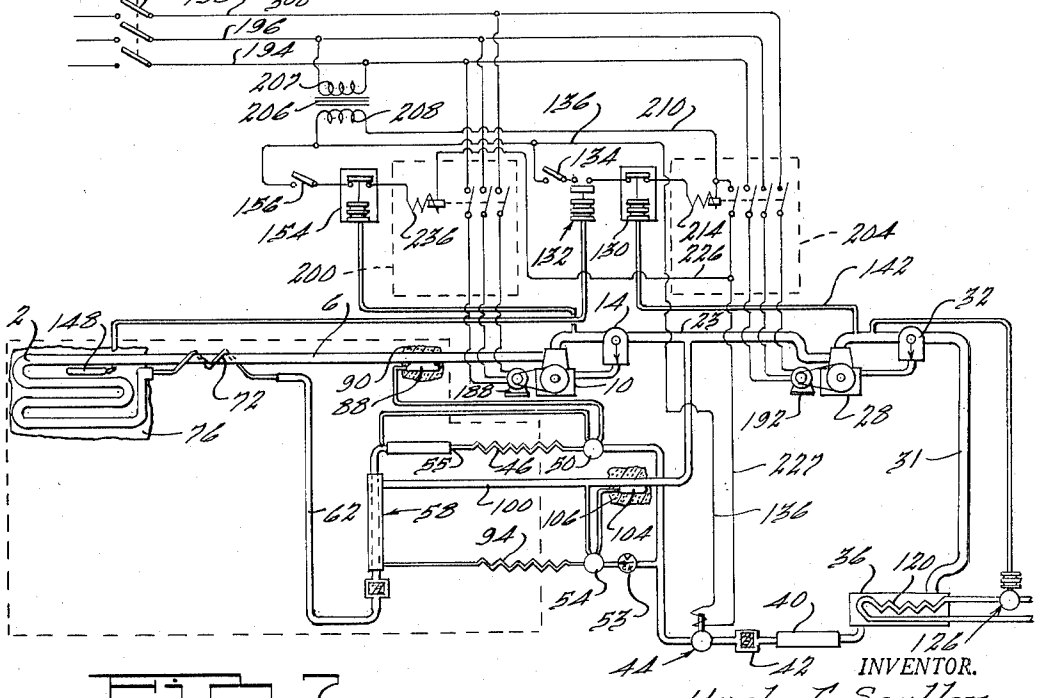

Fig. 7.

INVENTOR.
Hugh J. Scullen.
BY
Harness, Dickey & Pierce.
ATTORNEYS.

United States Patent Office 2,714,806 Patented Aug. 9, 1955

2,714,806

REFRIGERATING SYSTEM

Hugh J. Scullen, Detroit, Mich.

Application December 12, 1951, Serial No. 261,313

18 Claims. (Cl. 62—4)

This invention relates generally to a refrigerating system which is particularly adapted, among other uses, for maintaining low temperatures.

An object of this invention is to provide a new refrigerating system of the character described.

A further object is to provide such a system in which temperatures of the order of 150 degrees below zero or less may be maintained.

A further object is to provide such a system which will function to maintain a range of temperatures from 0 degrees Fahrenheit or above zero to 150 degrees below zero or below.

Another object is to provide such a system in which the heat is radiated from the system at usual radiating temperatures.

Another object is to provide such a system in which the pressure of the liquid refrigerant is reduced in a plurality of steps.

Another object is to provide such a plural step liquid refrigerant pressure reducing system with means for eliminating flash gas produced during the pressure reducing operations whereby a higher percentage of liquid is supplied to the evaporator.

Another object is to provide such a system in which the concentration of the circulating lubricant is maintained sufficiently low to provide proper operation of the system.

Another object is to provide means for removing wax from the circulating lubricant.

Another object is to maintain such a system using capillary tubes flow controlling devices at high operating efficiencies.

Another object is to provide such a system which uses plural stages of compression of the refrigerant removed from the evaporator.

Another object is to provide an automatic control of such compression stages so that the temperature of the cooled space may be widely varied.

Another object is to provide such a control for the compression stages which will insure a desired operating relation therebetween.

Other objects will be apparent from the description, the appended claims and the drawings in which drawings:

Figure 1 is a schematic view of a refrigerating system embodying the invention;

Fig. 2 is a detailed view of Fig. 1 showing the thermal heat bridges which were omitted in Fig. 1 for simplicity and for simplicity omits the showing of the compressor by-pass connections;

Fig. 3 is a detailed view of the reservoir of Fig. 1;

Fig. 4 is a detailed view of a modified form of reservoirs;

Fig. 5 is a view taken substantially along the line 5—5 of Fig. 4;

Fig. 6 is a schematic view of a modified form of system embodying the invention; and

Fig. 7 is a still further modified form of systems embodying the invention.

While there is shown herein three forms of the invention, in accordance with the patent statutes, these forms are to be taken as illustrative rather than limitative as various modifications thereof may be made within the scope of the invention which is claimed in the appended claims.

The numeral 2 designates an evaporator which might comprise coils wrapped around a metallic tank intermediate the tank and insulation which surrounds the tank. Vaporized refrigerant leaves the evaporator 2 through a suction line 6 to the inlet 8 of a reciprocating first stage compressor 10. The vaporized refrigerant passes from the compressor 10 through its outlet 12 and an oil separator 14 to the inlet 18 of the second stage compressor 20 by means of conduit 21. The outlet 22 of the compressor 20 is connected by conduit 23 through an oil separator 24 to the inlet 26 of a third stage compressor 28 having its outlet 30 connected by conduit 31 through another oil separator 32 to the inlet 34 of a water-cooled condenser 36, the outlet 38 of which is connected through a silica gel dryer 40, filter 42 and a solenoid valve 44 to the inlet 48 of a thermostatic expansion valve 50 and through branch conduit 52 and check valve 53 to a second thermostatic expansion valve 54. The outlet 51 of an expansion valve 50 is connected to the inlet of a capillary restrictor tube 46, the outlet of which is connected through silica gel dryer 55 to the inlet of 56 of a heat exchanger 58. The outlet 60 of exchanger 58 is connected through a filter 61 and conduit 62 to the inlet end of a capillary tube 64 the outlet end of which is connected to an inlet 66 of an expansion tank or container 68.

The expansion tank 68 has a liquid outlet 70 adjacent its bottom which is connected to the inlet end of a capillary tube 72 the outlet end of which is connected to the inlet 74 of the main evaporator 2 which is in heat exchange relation with the walls of an inner liner 76 shown fragmentarily and which is protected from ambient air by insulation as shown by the dash line 78. The expansion tank 68 has a second outlet 80 adjacent its top which is connected by a conduit 82 through a capillary tube 84 and check valve 86 to the conduit 21 intermediate the oil separator 14 and inlet 18 of compressor 20 whereby vaporous refrigerant may flow back to the compressor 20 without passing through the evaporator 2. The capillary tubes 72 and 84 are arranged in heat exchange relation with the conduits 6 and 21 respectively. The tube 72 is located in the insulation 78 while the tube 84 and most of the conduit 82 is located outside of the insulation 78 in the ambient air.

The expansion valve 50 is the type known as the equalizer type in which the pressure element is connected by a fluid pressure conveying conduit 87 to the conduit 82 intermediate the tank 68 and the restrictor tube 84. The expansion valve 50 also has a temperature controlling element 88 which is clamped to, or otherwise secured, in heat exchange relation with the conduit 6 externally of the insulation 78. The element 88 and adjacent portion of the conduit 6 are covered with insulation 90.

The expansion valve 54 is of the same type as the expansion valve 50 and its outlet 92 is connected to the inlet end of a capillary tube 94, the outlet of which is connected to a second inlet 96 of the heat exchanger 58. A second outlet 98 of this exchanger 58 is connected through a conduit 100 to conduit 23 and therethrough to the inlet 26 of the third stage compressor 28. A fluid pressure conveying tube 102 connects the pressure element of the valve 54 to the conduit 100 and the temperature element 104 is secured in heat exchange relation to the conduit 100 externally of the insulation 78. The element 104 and portion of conduit 100 to which it is in heat exchange relation are covered by insulation 106.

The water-cooled condenser **36** is provided with the usual water cooling coils **120** which are connected by means of conduits **122** and **124** to a suitable source of cooling water which flows from the source to the coils **120** under control of a pressure operated water regulating valve **126** whose control element **128** is connected by conduit **129** to the discharge conduit **31** whereby valve **126** is responsive to the discharge pressure of the compressor **28** and acts in the usual manner to increase the flow of coolant water upon an increase in discharge pressure.

As shown the compressors **10**, **20** and **28** are respectively driven by 3 phase motors **188**, **190** and **192**, however, it will be apparent that the number of phases is unimportant and also the compressors could be driven by other sources of power and controlled in the manner to be described. Electrical energy is supplied to the conductors **194**, **196** and **198** through the line switch LS–1. The conductors **194**, **196** and **198** are connected through line switch motor starters **200**, **202** and **204** to the motors **188**, **190** and **192** respectively. Single phase control power is obtained from the 3 phase source through a transformer **206** having its primary winding **207** connected between any two of the conductors which in the shown instance is connected between conductors **194** and **196**. A secondary winding **208** of transformer **206** has one terminal connected by conductor **210** to one terminal **212** of the operating coil **214** of the motor starter **204**. The other terminal of the coil **214** is connected by conductor **216** through a pressure switch **130**, thermostatic switch **132** and manual switch **134** to conductor **136** which is connected to the other terminal of the winding **208**. The switch **130** has a usual set of contacts **138** which are controlled by a pressure responsive element **140** connected by a pressure conveying conduit **142** to the discharge port or outlet **30** of compressor **28**. Increase in pressure at the discharge **30** of the compressor **28** above a predetermined pressure acts to open the contacts **138**.

The thermostatic switch **132** has a pair of contacts **144** which are controlled by means of a temperature sensitive element **146** having the usual bulb **148**. The bulb **148** is secured to the wall of the cabinet storage chamber liner **76** on the side thereof adjacent the insulation and intermediate a pair of turns of the evaporator **2** which is secured in heat exchange relation therewith. Upon increase in temperature above the predetermined desired temperature, the contacts **144** close. The motor starter **204** has main normally open contacts **218**, **220**, **222** closed upon energizatiton of the coil **214** which control the connection of the motor **192** to the conductors **194**, **196** and **198**. The motor starter **204** has a fourth contact **224** which is closed upon energization of the coil **214** to complete a circuit from the conductor **210** to a conductor **226** which is connected to one terminal **228** of the energizing winding **230** of the motor starter **202**. A branch conductor **227** of conductor **226** is connected to one terminal of the energizing coil of the solenoid valve **44** while the conductor **136** is connected to the other terminal of this coil so that the valve **44** will open and close upon opening and closing of the contact **224**.

The starter **202** is like the starter **204** and has contacts controlling the energization of the motor **190** and a fourth contact **232** closed upon energization of the coil **230**. The other terminal of the coil **230** is connected through a pressure switch **150** and manual switch **152** to the conductor **136**. The switch **150** is like the switch **130** but which has its element **154** connected to the conduit **23**. Closure of the contacts **232** connects the conductor **226** to a conductor **234** which is connected to one terminal of the operating coil **236** of the motor starter **200**. The motor starter **200** is like the starter **202** and **204** except that it needs no fourth contact or if present such contact is not used. Such starter **200** does have the main contacts which close as a consequence of the energization of the coil **236** to energize motor **188**. The other terminal of the coil **236** is connected through a pressure switch **154** and manual switch **156** to the conductor **136**.

The restrictors **46** and **94** maintain the expansion valves **50** and **54** at high enough temperature with respect to ambient temperature to avoid the difficulties which might otherwise occur due to frictional effects of congealing oil and sweating of the valves.

It is believed that the remainder of the construction may best be understood by a description of the operation of the system which is as follows:

Assuming that the system has been standing idle for a considerable period of time and the system parts are all at, or substantially at, ambient temperature and the thermostatic switch **132** is set to maintain a low temperature as for example 150 degrees Fahrenheit below zero. Under these conditions the pressure switches **150** and **154** will be open while switches **130** and **132** will be closed. The manual switches **134**, **152** and **156**, if not already closed, will be closed. Closure of line switch LS–1 will energize the conductors **194**, **196** and **198** and the transformer **206**. Control current will now flow from conductor **210** through coil **214** and switches **130**, **132** and **134** to cause coil **214** to close contacts **218**, **220**, **222** and **224**. Closure of contacts **218**—**222** causes motor **192** to start the compressor **28**. Closure of contact **224** causes the valve **44** to open and to energize conductor **226** to prepare for energization of coil **230** upon closure of switch **150** as will be described below. Upon operation of the compressor **28** suction vapor will flow from the main evaporator **2** through the other two compressors which under "pull down" conditions as described will not be operating since the pressures in the evaporator **2** will be so high as to maintain the pressure switches **150** and **154** open. In many compressors refrigerant can flow therethrough in a direction from the inlet to the outlet whenever the inlet pressure is greater than the outlet pressure even though the compressor is not running. In some instances it may be desirable to provide for by-passing the refrigerant around non-running compressors and for this purpose there is provided by-pass lines connecting the conduits **6** and **21**, and **21** and **23** in which are provided check valves **246** and **248**. A solenoid valve, connected to be opened when the compressor with which it is associated is running, may be used in place of the check valve.

As the compressor **28** operates, the temperature and corresponding pressure in the evaporator **2** will drop until, when the pressure in the evaporator **2** has reached approximately 20 pounds pressure, control **150** will close to complete the energizing circuit for coil **230** which then causes the contacts of the starter **202** to close to start compressor **20** and energize the conductor **234** as a preparatory circuit for energization of the coil **236**. Continued operation of compressors **20** and **28** results in a further drop in temperature and pressure in the main evaporator **2** until, at a pressure of approximately 10 inches of vacuum, the pressure control **154** will close to complete the energizing circuit for coil **236** which then causes the contacts of the starter **200** to close to start compressor **10**. Continued operation of compressors **28**, **20** and **10** will result in a further lowering of temperature in the evaporator **2** until the temperature of bulb **148** has been lowered to the cutout point of the thermostat **132**, at which time the thermostat will open is contacts **144** to de-energizing coil **214** which results in opening of the contacts **218**—**224** which de-energize motor **192**, valve **44** which then closes and coils **230** and **236** which causes the motor starters **202** and **200** to open their contacts and de-energize the motors **188** and **190**.

As the temperature of the liner **76** increases to the "cut-in-point" of the thermostat **132** its contacts again close initiating an operation of the compressor **28**. As-

suming that the operating temperature of the thermostat 132 has not been changed, the pressures in the conduits 21 and 23 will be within the pressure range at which the pressure switches 150 and 154 will be closed resulting in energization of the motor starters 202 and 200 and the motors 188 and 190 controlled thereby resulting in immediate restarting of all of the compressors 10, 20 and 28. This cycling condition will continue, assuming that no great heat loads have been placed in the cabinet, and the temperature of the cabinet will be maintained within the desired temperature range as determined by the differential operating temperature of the thermostat 132.

If the operating range of the thermostat 132 is adjusted to call for operation of the cabinet at a substantially higher temperature, then corresponding higher pressures will occur in the evaporator 2. An adjustment of the thermostat 132 to a temperature at which the operating evaporator pressure is above the pressure at which the switch 154 opens will cause the switch 154 to stand open and compressor 10 will not be operated. A still higher setting of the thermostat 132 will result in a higher operating evaporator pressure with the result that switch 150 will open and keep compressor 20 from operating.

The temperature range of the system may be from minus 120 degrees Fahrenheit in which cycling under control of the thermostat 132 causes operation of all of the compressors 10, 20 and 28, an intermediate temperature as, for example, minus 60 degrees Fahrenheit at which compressors 20 and 28 only would operate, and a higher temperature of, for example, 0 degrees Fahrenheit at which only the third stage compressor 28 would operate. The above temperatures are illustrative as the exact temperatures which would cause such operation may be varied somewhat, depending upon the particular design, by changing the pressure at which the switches 150 and 154 are set to open.

Because cabinets of this general type are desired to be operated in rooms normally maintained at temperatures for human comfort, and because the condenser 36, which is shown as liquid cooled but which could be air cooled, will be supplied with coolant which is of usual temperature generally in the neighborhood of 60 to 80 degrees Fahrenheit, the temperature and pressure of the liquid refrigerant supplied by the condenser 36 may be in the neighborhood of 80 to 100 degrees or even 120 degrees Fahrenheit under extreme conditions. If this liquid refrigerant were immediately allowed to expand into the evaporator 2, which may be operating as low as minus 140 degrees Fahrenheit to maintain temperatures of minus 120 degrees Fahrenheit within the liner 76, a considerable amount of this liquid would be turned into flash gas resulting from the heat abstracted from the liquid refrigerant in reducing its temperature from that of liquid supplied by the condenser 36 to the temperature of the liquid refrigerant in the evaporator 2. This would result in inefficient operation of the system since such flash gas would have to be compressed from the pressure appearing in the evaporator 2 to the discharge pressure of the compressor 28 requiring additional energy and larger compressors. In addition to the above inefficiencies, a certain amount of oil used to lubricate the compressors 10, 20 and 28 will also be flowing through the refrigerating system. Normally the percentage of oil flowing through such a system is small in proportion to the liquid supplied to the evaporator and will flow back to the compressor with the circulating refrigerant and a balance between refrigerant and lubricant is maintained in the various portions of the refrigerating system. If a large amount of liquid goes into flash gas to provide cooling of the liquid refrigerant supplied to the evaporator 2, the amount of lubricant or oil remains the same but since the amount of liquid refrigerant is less the percentage of oil, with respect to liquid refrigerant supplied to the evaporator, becomes excessive. Such excessive concentrations of oil cause further loss of efficiency and, in some cases, actual plugging of the orifices and other refrigerant supplying passageways and cases have been known in which the evaporator tubes themselves have been plugged.

The amount of flash gas supplied to the evaporator 2 is reduced by the heat exchanger 58 which recondenses the flash gas formed as a consequence of the initial reduction in pressure of the liquid refrigerant passing through the valve 50 and the restrictor 46. Again the accumulated flash gas formed as a consequence of the flow of refrigerant through the restrictor 64 and a portion of the circulating oil is removed through the conduit 82 so that little more than the flash gas formed as a consequence of the flow of refrigerant through the restrictor 72 passes into the evaporator 2. Thereby a big percentage of the flash gas is compressed from a higher pressure than that maintained in the evaporator 2 and also a desired portion of the lubricant is prevented from entering the evaporator 2 where it would cause undesirable results.

More specifically, liquid refrigerant in the system of Fig. 1 flows from the condenser 36 through the dryer 40 and filter 42 to the valves 50 and 54. Refrigerant flows through the valve 50 and restrictor 46 to the exchanger 58 wherein the flash gas is recondensed. The valve 50 cooperates with the restrictors 46, 64, 72 and 84 to control the refrigerant flow to the evaporator 2 as will be more specifically described hereinafter. The refrigerant then flows through the restrictor 64 to the reservoir 68. The resulting flash gas and some lubricant flows through the upper outlet 80, conduit 82 and restrictor 84 to the suction line 21 of the compressor 20. The liquid refrigerant and some oil collects in the bottom of the receptacle 68 and flows out through the lower outlet 70 and restrictor 72 to the evaporator 2. In order to reduce the amount of flash gas produced as a consequence of the final reduction in refrigerant pressure, the capillary tube or restrictor 72 is arranged in heat exchange relation with the suction line 6 within the insulation 78 so that the cold gaseous refrigerant flowing from the main evaporator 2 to the inlet 8 of the first stage compressor 10 will abstract as much heat as possible from the incoming refrigerant. The vapor formed in cooling the space defined by the liner 76 and some oil passes through conduit 6 to the inlet 8 of compressor 10 and then back to the condenser 36 where the heat thereof is removed and the refrigerant is condensed to a liquid. The oil separators 14, 24 and 32 act to collect and return some of the circulating oil but are not effective to prevent some oil from circulating throughout the system.

Valve 54 in cooperation with the restrictor 94 controls flow of refrigerant to the exchanger 58. The liquid refrigerant so admitted to the exchanger 58 vaporizes to cool and recondense the flash gas in the refrigerant flowing between the inlet 56 and outlet 60. The resulting vapor together with the flash gas formed as a consequence of refrigerant flow through restrictor 94 and any circulating oil then passes through the outlet 98 and conductors 100 and 23 to the inlet 26 of the compressor 28.

The valve 50 is of conventional construction but functions to provide an unusually high degree of superheat. This is because the equalizing or pressure connection 87 is responsive to the pressure of the refrigerant within the expansion tank 68, and its temperature responsive bulb 88 is in heat exchange relation with the suction line 6 intermediate the heat exchange relationship of the capillary tube 72 with the suction line 6 and the compressor inlet 8. Preferably the heat interchange between the capillary tube 72 and the suction line 6 raises the temperature of the gaseous refrigerant flowing through the suction line 6 so that when leaving the insulation 78 it is substantially at the same temperature as the temperature of the refrigerant in the container 68 which is very considerably above that in the evaporator 2. A superheat

of 50 degrees Fahrenheit has been found satisfactory with compressors and restrictors as follows:

Compressor	Capacity, C. F. M.
10	12
20	3
28	1.5

Restrictor	Length, feet	Internal Diameter, inches
46	10	.050
64	4	.050
72	10	.1275
94	10	.050
84	5	.050

when using F22 as the refrigerant. The proper heat exchange between the restrictor **72** and suction conduit **6** may be obtained by soldering about 3 feet of the restrictor **72** to substantially the same length of the conduit **6**.

Initially under "pull down" conditions, the valve **50** will normally be in a fully open condition. As the temperature of the evaporator lowers to an intermediate temperature, which for purposes of illustration will be assumed to be 30 degrees Fahrenheit below zero, the valve **50** will commence to throttle the fluid flow to the restrictors. Such temperature could well be above or below this temperature depending upon design factors. As the intermediate temperature is reached the restriction to flow offered by the restrictors when related to the temperature of the liquid refrigerant in the condenser **36** is such that the flow of refrigerant entering the evaporator **2** would result in a greater rate of flow of refrigerant entering the evaporator than being removed therefrom. Continued lowering of the evaporator temperature and consequently of the pressure of the refrigerant therein results in a progressively greater pressure differential between that of the evaporator **2** and the condenser **36** and an increased flow of refrigerant to the evaporator **2**. Such increased flow results in a reduction in temperature of the bulb **88** since the superheated refrigerant vapor acting on the bulb **88** is at a lower temperature. There may even be some tendency for small amounts of liquid refrigerant to flow into the conduit **6**, thus lowering of the temperature of the bulb **88** still further. As the bulb temperature decreases, the valve **50** moves further toward the closed position and cooperates with the restrictors to limit the refrigerant flow to the evaporator **2** to maintain the desired amount of liquid therein. The inherent characteristic of a thermostatic expansion valve of decreasing the degree of superheat required to actuate the valve as a function of increase in evaporator temperature and pressure aids the valve in maintaining its open condition during pull down and acting as a throttling valve during normal low temperature running.

The restrictor **84** is arranged in heat exchange relation with the conduit **21** which is normally maintained at a higher temperature, though the pressure of refrigerant therein is lower, than that of the container **68**. Normally the refrigerant flowing through the restrictor **84** is vaporous and any further superheating has little effect on the rate of flow through the restrictor. If, however, liquid refigerant flows into the container **68** faster than it flows out of the outlet **70** the level thereof will rise and finally flow out into the conduit **82**. Such liquid refrigerant will pick up heat from the ambient air surrounding the portion of the conduit external of the insulation **78** and vaporize substantially increasing the amount of vapor which the restrictor **84** is required to pass and increasing the pressure drop therethrough. This results in an increase in pressure in the container and an increased flow of liquid refrigerant to the evaporator **2** through the restrictor **72**. Increase in pressure in the container **68** will tend to reduce flow of refrigerant through the restictor **64** and liquid may tend to back up in the exchanger and even to the extent that the inner tube connecting outlet **60** with inlet **56** will completely fill with liquid which is, of course, subcooled by the evaporating refrigerant in the shell connecting the inlet **96** and outlet **98**. This will result in a tendency for the restrictor **46** to pass less refrigerant. However, such increases in pressure will result in the production of less flash gas and more cooling by the exchanger **58** so that the net result will be increased pressure in the system for forcing the normal amount of refrigerant into the evaporator **2**.

A portion of the restrictors **46** and **94** are located external of the insulation **78** as are the valves **50** and **54**. Restrictor **46** provides a sufficient pressure drop between the outlet of the expansion valve **50** and the temperature maintained in the heat exchanger **58** so that the temperature of the valve **50** is maintained high enough to prevent excessive sweating and substantial drag in the operation of the valve which might otherwise occur due to low temperature of the oil therein. Smoother operation of the valve and more even flow of refrigerant therethrough is thereby provided. The valve **54** is similarly maintained for smooth operation and prevented from excessive sweating.

The valve **54** cooperates with the restrictor **94** in much the same way as does the valve **50** with the restrictors **46**, **64** and **72** to maintain a desired refrigerant flow to the exchanger **58**. Initially at "pull down" the pressure difference across the compressor **28** is small and valve **54** will be wide open. As the pressure and temperature of the low pressure portions of the system decreases the pressure difference across the compressor **28** increases and the valve **54** acts to prevent excessive quantities of refrigerant from flowing to the exchanger **58** and flood back through the conduit **100**. It should further be noted that the temperature of the exchanger **58** will drop during "pull down" resulting in a reduced pressure of the refrigerant flowing through the restrictor **64** which will tend to reduce refrigerant flow through the restrictor **72** to the evaporator **2**. Fluid flow to the restrictor **64** and **72** is further infiuenced by restrictor **84**. The inherent tendency of the condenser **36** to reduce its operating pressure as a consequence of a reduction in the pressure in the evaporator **2** also aids in maintaining the proper flow of refrigerant in the system.

Since capillary tubes are essentially fixed value restrictors, and as such are designed for maximum system efficiency at one desired operating condition of the system, their use has been somewhat limited to systems operating within a relatively narrow temperature range. With the illustrated system the range over which efficient operation of the system is increased many fold both due to the presence of the valves **50** and **54** which act to prevent excessive liquid being supplied to the exchanger **58** and evaporator **2** and due to the compensating effect provided by the exchanger **58** and restrictor **84** which cooperate together to provide for a greater flow to refrigerant to the evaporator **2** in part at least due to the variable pressure drops mentioned above resulting as a consequence of liquid build up in the reservoir **68**.

In Figure 2 there is shown a detail of the system of Fig. 1 in which thermal bridges **250**, **252** and **254** have been provided to modify the action of the valve **50** as a function of the temperature of the discharge vapors of the compressors **10**, **20** and **28**. For simplicity the showing of the by-pass connections, including the check valves **246** and **248**, have been omitted in Fig. 2. While three bridges **250**, **252** and **254** are shown and the presence thereof provides certain beneficial results, within the generic scope of the invention, one or more are not essential to the functioning of the system. The bridges **250**, **252** and **254** are designed to function during the operation of the system when the valve **50** is tending to throt-

tle refrigerant flow. They are shown as being straps of suitable material such as copper, aluminum or other good heat conducting material and serve to transfer some heat from the discharge of the compressors **10**, **20** and **28** back to the conduit **6** adjacent the bulb **88**. The exact location of the bridges on the conduit **6** is not to important except that they must be able to influence the temperature of bulb **88**. In the event of abnormal discharge temperature of the compressors **10**, **20** and/or **28**, the bridges **250**, **252** and/or **254** will raise the temperature of the bulb **88** slightly above the temperature it would otherwise assume and tend to open the valve to provide for a greater flow of refrigerant to the evaporator **2** which results in a cooler temperature of the refrigerant flowing to the compressor inlets. In some instances it may be desirable to even raise the temperature of the bulb **88** sufficiently to permit some liquid refrigerant to flow past the bulb **88** but such amount should not be great enough to flood liquid into any of the compressors. A similar bridge **256** may be provided between the conduits **31** and **100** to heat the bulb **104** whereby additional refrigerant will be admitted to the exchanger **58** and the temperature of the refrigerant flowing to the inlet **26** of the compressor **28** will be lowered due to the lower temperature of the refrigerant flowing from the conduit **100**.

In Fig. 3 there is shown a detail of the reservoir **68** which not only functions as above described but which also functions to remove wax from the circulating refrigerant. The already rather cold liquid refrigerant and entrained oil enters the reservoir **68** at high velocity from the end of the capillary tube **64** which extends through the inlet **66**. The refrigerant and entrained oil upon entering the interior of reservoir **68** rapidly expands and reduces in temperature and velocity and any wax in the oil tends to separate out as wax particles which then collect on the internal fine mesh screen **260**.

Figs. 4 and 5 show a modified form of reservoir **68'** in which the capillary tube **64** discharges tangentially into the reservoir **68'** and the wax which may be formed as above tends to be thrown against and adhere to the internal walls of reservoir **68'**. The separation of wax at this stage in a relatively large space prevents its formation in the rather small bore restrictor **72** or in the evaporator **2** where it might collect and plug the system.

During off time of the refrigerating system the solenoid valve **44** will be de-energized and closed to prevent draining of the liquid refrigerant from the condenser **36** into the low pressure side of the system. Check valves **53** and **86** are provided to prevent draining of other intermediate pressure portions of the system back to the evaporator **2**. This is necessary since during off time, the temperature of the thermostatic element **88** and **104** of the valves **50** and **54** will increase substantially above operating temperatures and cause the respective valves **50** and **54** to remain open.

The system of Fig. 6, in which parts corresponding to those in Fig. 1 are identified by the same reference characters, is similar to the operation of the system of Fig. 1 except that the heat exchanger **58** of Fig. 1 has been replaced by a second container **300** similar to the container **68** in which the flash gas, resulting as a consequence of the flow of liquid refrigerant through the restrictor **46**, is removed through the conduit **302** and restrictor **304** to the conduit **23** which is in open communication with the inlet **26** of the compressor **28**. The container **300** like container **68** is provided with an inlet **306** to which the outlet end of the restrictor **46** is connected and with a lower outlet **308** which is connected to supply liquid to the restrictor **64**. The conduit **302** is connected to the upper outlet **310**. A major portion of the conduit **302** is located externally of the insulation **78** and the restrictor **304** is arranged in heat exchange relation with the conduit **23**. A check valve **312**, similar to the check valve **86**, is provided to prevent reverse flow of fluid through the restrictor **304** and conduit **302**.

The operation of this system is similar to that of the system of Fig. 1 except that the flash gas which forms between the restrictor **46** and **64** is collected in container **300** and conducted back to the compressor **28** through conduit **302**, along with some oil, rather than recondensed as in Fig. 1. Restrictor **304** cooperates with the container **300**, similarly as does the restrictor **84** and conduit **82** with the container **68**, to provide for an increased pressure in the container **300** in the event that the container **300** fills and liquid tends to flow outwardly of the outlet **310** into the conduit **302**.

The system of Fig. 7 is similar to that of Fig. 1 except that the second stage compressor **20**, the restrictor **64**, the container **68** together with its conduit **82** and restrictor **84** and certain associated parts have been omitted. This system is particularly adapted for applications wherein the temperature to be maintained within the shell **76** are not required to be as low as the minimum temperatures desired within the shells **76** of the systems of Figs. 1 and 6.

It will be noted that while the valves **50** are shown in connection with both the systems of Figs. 1 and 7 and not with the system of Fig. 6, the valves could be used with the system of Fig. 6 or could be omitted from the systems of Figs. 1 and 7 if desired. As explained above during normal operation the valves **50** are maintained open and throttle refrigerant flow when necessary to prevent "flood-back" of the refrigerant from the evaporator **2**.

While capillary tube type restrictors are shown and their use provides certain desirable operating features of the refrigerating system, the invention also contemplates the use of other types of liquid refrigerant feeding devices such as automatic or thermostatic expansion valves, low side float devices, etc. which may be used to regulate the liquid flow through a plurality of reducing stages in place of the shown restrictors either with or without the valves **50**. In such event the flash gas will be eliminated either by recondensing such gas or by removing it or a combination of the two methods.

What is claimed and is desired to be secured by United States Letters Patent is as follows:

1. In a refrigerating system for cooling a space, an evaporator having an inlet and an outlet and arranged in heat exchange relation with such space, at least three refrigerant compressors each having a suction connection, and a discharge connection and a connection for returning lubricant thereto, a condenser for refrigerant having an inlet and an outlet means providing a first fluid flow passageway from said discharge connection of one of said compressors to said condenser inlet, means providing a second fluid flow passageway connecting said condenser outlet to said evaporator inlet, a third fluid flow passageway connecting said discharge connection of a second of said compressors to said first compressor suction connection, a fourth fluid flow passageway connecting said evaporator outlet with said suction connection of a third of said compressors, a fifth fluid flow passageway connecting said third compressor discharge connection to said second compressor suction connection, a plurality of lubricant separators individually connected with said discharge connection of said compressors, said separation having a lubricant return connection connected to said lubricant connection of the one of said compressors with which it is individually associated, said second passageway including three flow controlling devices arranged in series therein, means including said first said compressor for substantially eliminating flash gas formed as a consequence of flow of liquid refrigerant through a first of said devices, means including said first and said second compressors for substantially eliminating the flash gas formed as a consequence of flow of liquid refrigerant through a second of said devices, means responsive to the temperature of said space for controlling

the operation of said first compressor, means responsive to an operating condition of said first compressor for controlling the operation of said second compressor, and means responsive to an operating condition of said second compressor for controlling the operation of said third compressor.

2. The combination of claim 1 in which said devices are small bore tubes.

3. The combination of claim 1 in which at least one of said flash gas eliminating means includes a small bore tube.

4. In a refrigerating system for cooling a space, an evaporator in heat exchange relation with such space, a liquid refrigerant container normally maintained at a temperature elevated with respect to that of such space, a fluid conveying passageway connecting said container to said evaporator and including a pair of flow controlling devices serially arranged between said container and said evaporator, and a second refrigerant evaporator connected in parallel with said first named evaporator and in heat exchange relation with said passageway intermediate said devices to cause condensation of the flash gas resulting from the passage of refrigerant through a first of said devices.

5. The combination of claim 4 in which at least one of said devices is a section of small bore tubing.

6. In a refrigerating system for cooling a space, an evaporator in heat exchange relation with such space, a liquid refrigerant container normally maintained at a temperature elevated with respect to that of such space, a fluid conveying passageway connecting said container to said evaporator and including a pair of flow controlling devices serially arranged between said container and said evaporator, means for cooling at least a portion of said passageway intermediate said devices to cause condensation of the flash gas resulting from the passage of refrigerant through a first of said devices, a section of small bore tubing and a fluid container serially arranged in the order recited in said passageway between said passageway cooled portion and the second of said devices, said container having an inlet for receiving refrigerant passed by said first device and a pair of outlets, one of said outlets being at a lower elevation than the other thereof, said lower outlet being connected to supply refrigerant to said second device, and means for removing refrigerant from the said other container outlet in by-pass relation to said evaporator.

7. The combination of claim 6 in which a thermostatic expansion valve is provided intermediate said container and said first device to control flow of refrigerant to said first device from said container, said valve having a thermostatic control element and a pressure control element, said thermostatic element being arranged to be responsive to a function of the temperature of the refrigerant in said evaporator and said pressure element being responsive to the pressure in said passageway intermediate said first and said second control devices.

8. In a refrigerating system for cooling a space, an evaporator arranged in heat exchange relation with such space and having an inlet and an outlet, insulation around such space, a plurality of refrigerant compressors located externally of said insulation and said space and each provided with a suction and a discharge port, a condenser located externally of said insulation and said space and having an inlet and an outlet and arranged to be cooled whereby vaporous refrigerant may be condensed therein, a first conduit connecting said discharge port of one of said compressors to said condenser inlet, a second conduit connecting said discharge port of a second of said compressors to said first compressor suction port, a first and a second section of small bore fluid flow controlling tubing arranged in series between said condenser outlet and said evaporator inlet, a fluid container serially arranged between said tubing section, said container having an inlet for receiving refrigerant from said first tubing section and a first outlet adjacent its bottom portion for supplying liquid refrigerant to said second tubing section, a third section of small bore fluid flow controlling tubing serially arranged between said container inlet and said first tubing section, means including said first compressor for eliminating flash gas from the refrigerant intermediate said first and said third tubing sections, said container having a second outlet located at an elevation higher than said container first outlet, fluid flow passageway means including a fourth section of small bore fluid flow controlling tubing connecting said container second outlet with said second compressor suction port, a third conduit connecting said discharge port of a third of said compressors with said second compressor inlet port, a fourth conduit connecting said evaporator outlet with said third compressor inlet port, at least a portion of said fourth tubing section being arranged in heat exchange relation with fluid in said third conduit, at least a portion of said second tubing section being arranged in heat exchange relation with fluid in said fourth conduit, a thermostatic expansion valve arranged in series between said condenser outlet and said first tubing section, said valve having a pressure sensitive element and a temperature sensitive element, said second and third tubing sections and at least a portion of said first tubing section and said container being located so as to be protected from ambient temperatures by said insulation, a length of said fourth conduit and said third conduit and said fourth tubing section being exposed to ambient temperature, said temperature sensitive element being arranged in heat exchange relation with an intermediate portion of said fourth conduit length, insulating covering said temperature element and said fourth conduit intermediate portion, valve means normally preventing fluid flow to said first tubing section, means responsive to a function of the operating condition of said evaporator for controlling said first compressor means rendering said valve means in condition to permit fluid flow concurrently with the operating of said first compressor, means responsive to an operating condition of said first compressor to control said second compressor, and means responsive to an operating condition of said second compressor to control said third compressor.

9. The combination of claim 8 in which a second evaporator is arranged in heat exchange relation with the fluid passed by said first tubing section, said second evaporator having an outlet communicatively connected to said first compressor inlet and being supplied with a controlled quantity of refrigerant from said condenser.

10. In a refrigerating system, a high pressure side including a compressor having an inlet and an outlet, a low pressure side, a thermostatic expansion valve having an inlet and an outlet and a temperature sensitive bulb, fluid flow means connecting said valve inlet to said high side on the outlet side of said compressor, fluid flow means connecting said valve outlet to said low side, fluid flow means connecting said low side to said high side on the inlet side of said compressor, said bulb being in heat exchange relation with said last named fluid flow means, and heat transfer means between said bulb and said high side adjacent said compressor outlet.

11. In a refrigerating system, a high pressure side including a compressor, a low pressure side including an evaporator and a compressor connected in serial arrangement, a space to be cooled in heat exchange relationship with said evaporator, a thermostatic expansion valve located outside said space so as to operate at a higher temperature than prevails therein and having an inlet and an outlet and a temperature sensitive bulb, fluid flow means connecting said valve inlet to said high side on the outlet side of said compressor, fluid flow means connecting said valve outlet to said low side on the inlet side of said evaporator and including a pair of serially arranged, small bore, flow restricting tubes and a refrigerant heat exchanger serially connected between said tubes, and fluid flow means connection, in by-pass arrangement with respect to said low side, said high side to the cooling cham-

ber of the said refrigerant heat exchanger for supplying refrigerant thereto for cooling the refrigerant passing directly through said heat exchanger to the said evaporator inlet, the bulb of said thermostatic valve being in heat exchange relationship with said low side between the outlet of said evaporator and the inlet of said compressor so as to respond to the temperature therein prevailing for the purpose of controlling the amount of cooled refrigerant supplied to said evaporator.

12. In a refrigerating system, a high pressure side including a compressor, a low pressure side including an evaporator and a compressor connected in serial arrangement, a space to be cooled in heat exchange relationship with said evaporator, a thermostatic expansion valve located outside said space so as to operate at a temperature higher than prevails therein and having an inlet, outlet and a temperature sensitive bulb, fluid flow means connecting said valve inlet to said high side on the outlet side of said compressor, fluid flow means connecting said valve outlet to said low side on the inlet side of said evaporator and including a pair of serially arranged small bore, flow restricting tubes and a refrigerant heat exchanger serially connected between said tubes, fluid flow means connecting, in by-pass arrangement with respect to said low side and said compressor therein, said high side to the cooling chamber of the said refrigerant heat exchanger for supplying refrigerant for cooling the refrigerant passing directly through said heat exchanger to said evaporator inlet and including a thermostatic expansion valve located outside said space and a small bore, flow restricting tube connected in serial arrangement, the bulb of the first said thermostatic expansion valve being in heat exchange relationship with said low side between the outlet of said evaporator and the inlet of said compressor so as to respond to the temperature therein prevailing for the purpose of controlling the amount of cooled refrigerant to be supplied to said evaporator and the bulb of the second said thermostatic expansion valve being in heat exchange relationship with the effluent of the cooling chamber of the said heat exchanger for controlling the amount of refrigerant supplied to the said cooling chamber of said heat exchanger.

13. In a refrigerating system, an evaporator, a condenser, at least a pair of refrigerant compressors each having an inlet and an outlet, conduit means connecting said compressors in series between said evaporator and said condenser for transferring refrigerant from said evaporator to said condenser, means for conveying refrigerant to said evaporator from said condenser and including at least a pair of serially connected flow controlling devices, a flash gas collecting vessel located in said conveying means intermediate said flow controlling devices and through which refrigerant that is supplied to said evaporator necessarily flows, a second conduit means, including a length of small bore tubing, connecting said flash gas collecting vessel with said first named conduit means and at a point which is intermediate said compressors, said length of small bore tubing also being arranged in heat exchange relation with said first named conduit means intermediate said compressors.

14. The combination of claim 13 in which said flash gas vessel has an inlet and a pair of outlets, said inlet of said vessel being connected to receive refrigerant from one of said flow devices, one of said outlets of said vessel being located in a low portion of said vessel and connected to discharge refrigerant to the other of said flow devices, the other of said outlets of said vessel being elevated with respect to said one outlet and connected to said second conduit means.

15. In a refrigerating structure, an insulated cabinet having an internal chamber insulated from the external surroundings, an evaporator in heat exchange relation with said chamber for removing heat therefrom, a condensing unit located externally of said cabinet, fluid flow means connecting said unit and said evaporator into a closed system and including a vapor conveying conduit for flow of refrigerant from said evaporator to said unit and a liquid conveying conduit for flow of refrigerant from said unit to said evaporator, each of said conduits having portions external of said cabinet, said liquid conveying conduit including a restricting device, at least a portion of said restricting device being located within the insulated portion of said cabinet, a thermostatically controlled expansion device located in said liquid conveying conduit externally of said cabinet and having a pressure sensitive element and a temperature sensitive element, means for heating said vapor conveying conduit, said temperature sensitive element being arranged in heat exchange relation with a portion of said vapor conveying conduit intermediate said heating means and said condensing unit, said restricting device acting to reduce the pressure of the fluid flowing therethrough and having a portion thereof in which the pressure of the fluid is substantially at or above the saturated pressure of the same fluid at the ambient temperature of said cabinet, and means connecting said pressure element to said closed system at said portion of said restricting device.

16. The combination of claim 15 in which said condensing unit includes a pressure increasing device and said heating means comprises a heat transfer connection between said vapor conveying conduit and the discharge side of said pressure increasing device.

17. In a refrigerating structure, an evaporator, a condensing unit having two pressure increasing stages, fluid flow means connecting said unit and said evaporator into a closed system, said system including a vapor conveying conduit for flow of refrigerant from said evaporator to said unit and a liquid conveying conduit for flow of refrigerant from said unit to said evaporator, said liquid conveying conduit including a restricting device, a thermostatically controlled expansion device located in said liquid conveying conduit having a pressure sensitive element and a temperature sensitive element, means for heating said vapor conveying conduit, said temperature sensitive element being arranged in heat exchange relation with a portion of said vapor conveying conduit intermediate said heating means and said condensing unit, and fluid pressure conveying means connecting said pressure element to respond to the pressure in said unit intermediate said pressure increasing stages.

18. The combination of claim 17 in which control means is provided to control the periods during which said condensing unit is effective to transfer refrigerant, a valve in said liquid conveying conduit, control means connected to actuate said valve between open and closed positions and normally effective to maintain said valve closed, said last named means being operable during periods in which said condensing unit is transferring refrigerant to open said valve.

References Cited in the file of this patent

UNITED STATES PATENTS

1,106,244	Schliemann	Aug. 4, 1914
2,116,100	Cracknell	May 3, 1938
2,318,318	Lodwig	May 4, 1943
2,402,802	Carter	June 25, 1946
2,453,095	McGrath	Nov. 2, 1948
2,500,688	Kellie	Mar. 14, 1950
2,520,045	McGrath	Aug. 22, 1950

FOREIGN PATENTS

133,012	Switzerland	July 16, 1929
656,641	France	May 10, 1929