Aug. 12, 1947. G. MUFFLY 2,425,634

CONTROL METHOD AND ARRANGEMENT FOR A TWO TEMPERATURE REFRIGERATOR USING A CAPILLARY EXPANSION DEVICE

Original Filed July 18, 1940 2 Sheets-Sheet 1

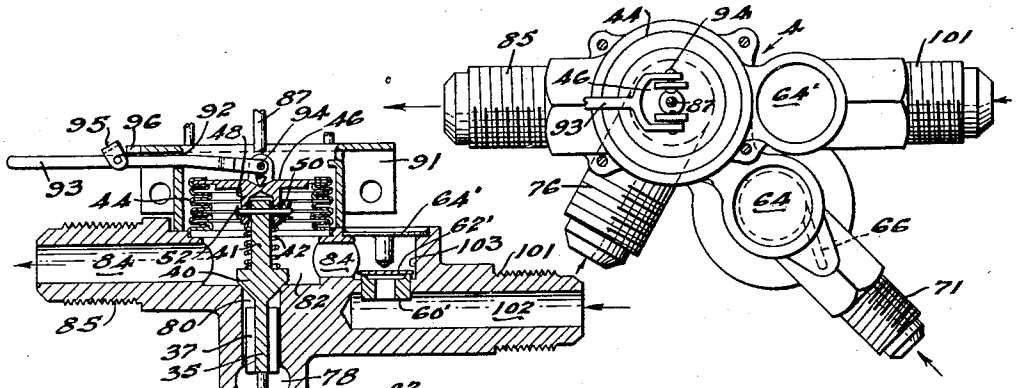


FIG. 2.

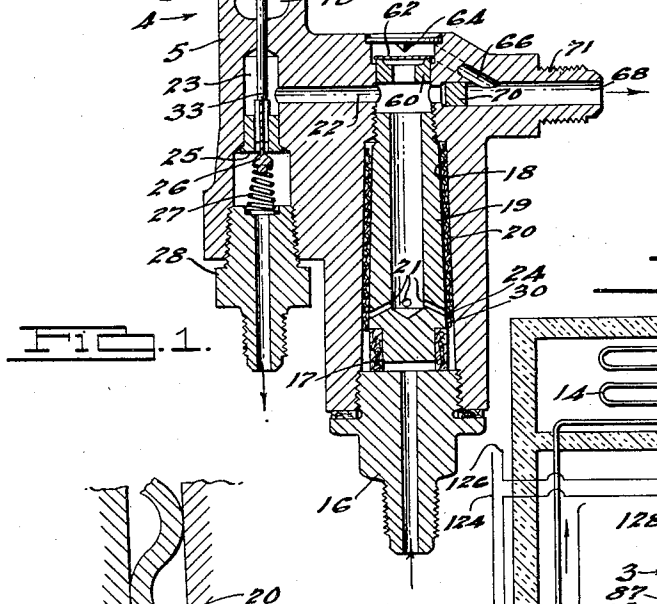


FIG. 1.

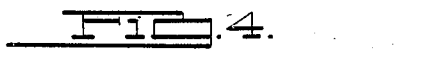


FIG. 4.

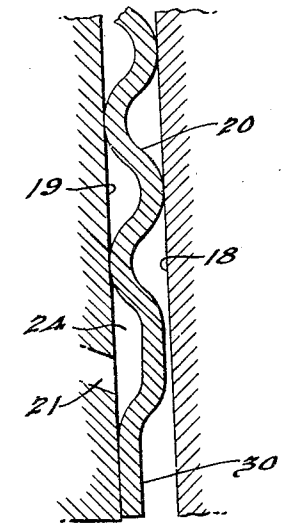
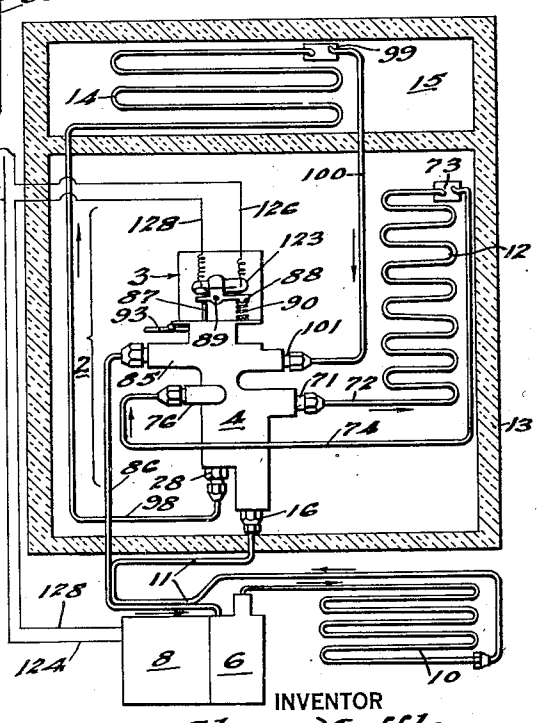


FIG. 3.



INVENTOR
Glenn Muffly.
BY
Harness, Dickey & Pierce.
ATTORNEYS.

Aug. 12, 1947. G. MUFFLY 2,425,634

CONTROL METHOD AND ARRANGEMENT FOR A TWO TEMPERATURE REFRIGERATOR USING A CAPILLARY EXPANSION DEVICE

Original Filed July 18, 1940 2 Sheets-Sheet 2

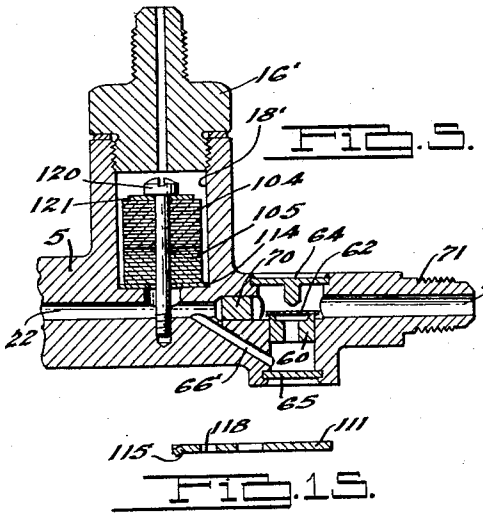


FIG. 5.

FIG. 15.

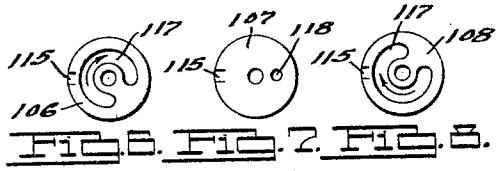


FIG. 6. FIG. 7. FIG. 8.

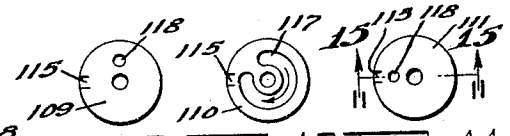


FIG. 9. FIG. 10. FIG. 11.

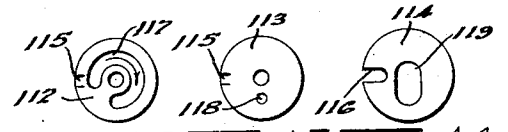


FIG. 12. FIG. 13. FIG. 14.

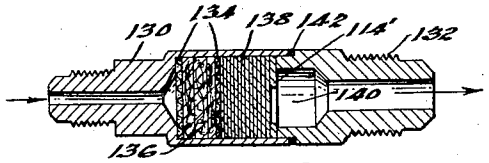


FIG. 16.

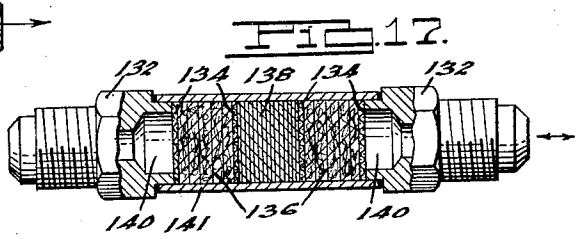


FIG. 17.

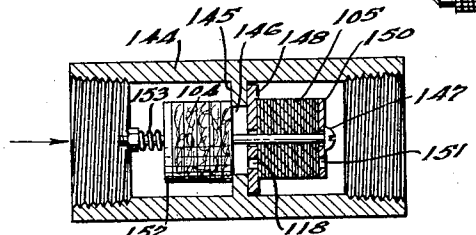


FIG. 18.

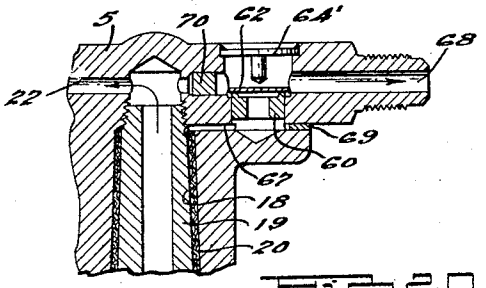


FIG. 20.

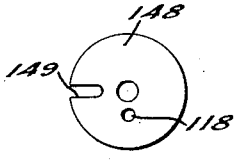


FIG. 19.

INVENTOR
Glenn Muffly.
BY
Harness, Dickey & Pierce
ATTORNEYS.

Patented Aug. 12, 1947 2,425,634

UNITED STATES PATENT OFFICE

2,425,634

CONTROL METHOD AND ARRANGEMENT FOR A TWO TEMPERATURE REFRIGERATOR USING A CAPILLARY EXPANSION DEVICE

Glenn Muffly, Springfield, Ohio

Continuation of application Serial No. 346,085, July 18, 1940. This application March 1, 1943, Serial No. 477,519

17 Claims. (Cl. 62—3)

1

This invention pertains to control devices for regulating and directing the flow of refrigerant in both the liquid and vapor phases in a refrigerating system and particularly to the use of a capillary device for creating a back pressure upon the refrigerant vapor in the condenser; to controlling refrigerant flow in a two-temperature system and to making a single expansion device operate properly to regulate the flow of refrigerant to each of two or more evaporators.

The present application is a continuation of my application for Letters Patent of the United States for improvements in Refrigerating mechanism, filed July 18, 1940, and serially numbered 346,085.

An object of this invention is to provide a vapor-lock type of expansion device having means for immediately cooling upon starting of the system to avoid an excessive degree of vapor-lock effect at the start of an operating cycle of the system.

Another object is to adapt a single expansion device for use in regulating the flow of refrigerant to a pair of evaporators operated at different evaporating pressures.

An additional object is to provide a capillary expansion device arranged to serve two evaporators and to trap a charge of liquid refrigerant in each of a pair of evaporators when they are both idle and in the idle one when only one is idle.

Another object is to provide a capillary expansion device formed by a spirally corrugated shell fitted within a bore and around a core.

A further object is to provide a capillary expansion device that is readily cleanable and associated with a removable filter.

An additional object is to provide a valve mechanism for selectively refrigerating a pair of evaporators and to provide said device with means operable externally for putting the entire low side of the system in communication with the suction side of the compressor for the purpose of evacuating the system.

Another object is to provide an improved form of heat exchange for cooling the liquid refrigerant prior to its passage into the flow regulating device.

Still another object is to provide a pair of co-acting valves, one controlling the inlet of liquid refrigerant to one evaporator and the other controlling the outlet of the other evaporator, together with a mechanical connection between said valves arranged to minimize fluid leakage between the separate passages leading to the respective valves.

2

When the term "vapor-lock" appears in this specification or in a claim it refers to that general class of refrigerant flow controlling devices commonly referred to as "capillary tubes," as "restrictors," as "orifices," as "fixed passages of restricted diameter," etc., the term "vapor-lock" being used because it defines more exactly how such devices operate to substantially prevent flow of vapor therethrough during operation of the compressor, to be affected by temperature changes and yet remain open to allow a relatively slow flow of vapor sufficient to substantially equalize pressures during idle periods.

In the accompanying drawings, where similar reference numbers represent similar parts:

Fig. 1 is a vertical sectional view through a valve mechanism and capillary control device adapted for use in a two-temperature refrigerating system;

Fig. 2 is a plan view of the valve and refrigerant control device seen in Fig. 1;

Fig. 3 is an enlarged detail sectional view showing a portion of the capillary device of Fig. 1;

Fig. 4 is a more or less diagrammatic view of a complete refrigerating system including the apparatus seen in the preceding views, showing its relation to the evaporators and to the switch for controlling and the starting and stopping of the system;

Fig. 5 is an alternative construction of the filter and capillary expander parts of Fig. 1;

Figs. 6 to 13, inclusive, are details of the various discs used in Fig. 5 to make up the capillary stack 105.

Fig. 14 shows the heavier disc 114 used in Fig. 5 below the capillary discs;

Fig. 15 is a sectional view of Fig. 11, showing how the various discs are locked together;

Fig. 16 is a sectional view of an assembly including a filter and a set of capillary discs, both being retained by their outside diameters instead of by a central screw as seen in Fig. 5;

Fig. 17 is a sectional view similar to Fig. 16 but showing a filter on each side of the stack of capillary discs to provide for the flow of refrigerant in either direction;

Fig. 18 is a sectional view illustrating a modified form of housing for the filter and capillary discs;

Fig. 19 shows the special disc 148 which is used in Fig. 18; and,

Fig. 20 is a fractional sectional view showing a slight modification of Fig. 1 to illustrate a vari-

ation of the method for passing refrigerant to the warmer evaporator.

Referring to Fig. 1 we see the valve parts in the positions they assume at the end of an operating cycle of the system, with valve 26 open, valve 40 closed and bellows 44 compressed.

A pressure rise in passage 78, which connects through union 76 and tube 74 (Fig. 4) with the warmer evaporator 12, will lift the valve 40 (Fig. 1) from its seat due to clearance around pin 52. This allows vapor from the warmer evaporator to enter the chamber 82 and the bellows 44. This pressure will expand the bellows 44, carrying its head 46 and the push rod 87 upwardly to the point of tilting rocker 88 (Fig. 4) on its pivot 89, causing the switch 123 to close the circuit 126—128—124 of motor 8 and start the compressor 6. The compressor now draws refrigerant vapor from the warmer evaporator 12 through tube 74 and passages 78 and 80, upwardly past the flutes 37 of valve stem 35 (Fig. 1), past valve 40, through chamber 82, passage 84, union 85 and tube 86 to the suction side of compressor 6.

As this vapor is compressed and delivered to the condenser 10 the pressure rises to the condensing point due to the fact that vapor cannot pass the vapor lock device 18—19—20 of Fig. 1 as rapidly as it is pumped by the compressor 6. As the refrigerant liquefies in the condenser 10 and passes through the tube 11, the union 16 and the filter 17 it is further passed between the spirally corrugated shell 20 and the wall of the chamber 18 to the upper extremity of the shell 20, at which point it is free to enter the spiral passage between the part 20 and the core 19.

The liquid thus returns to near the bottom of the parts 19 and 20 and passes from the spiral passage or from the annular passage 24 through one of the drilled holes 21 to the bore within the part 19. Due to the larger cross-section of this bore the liquid now starts evaporating, but the bulk of the liquid, along with what vapor has already been formed, flows upwardly through the valve seat 60, lifting the check valve 62 to flow through the passages 66 and 68 and through tube 72 to the higher temperature "box" evaporator 12.

It will be understood that liquid refrigerant cannot flow through the passage 22 and past the valve 26, since this valve was closed by the spring 27 at the time the valve 40 was lifted from its seat. It should also be noted that we are now operating on the higher pressure one of the two evaporators, hence none of the vapor from the "freezer" or lower temperature evaporator 14 can lift the valve 62'. The freezer is, therefore, isolated by the valves 26 and 62' so that the system operates for the time being as if there were only the one evaporator 12. The area of the port of the valve 26 and the strength of the spring 27 are so proportioned that the valve 26 will not be opened by liquid pressure in the chamber 23 during the time that the warmer evaporator is in operation. The area of the port closed by the valve 26 is for this reason made quite small. A very small opening will suffice to pass liquid at this point.

As the evaporator 12, located in the main food compartment of the refrigerator 13 in Fig. 4, is cooled the pressure within the suction tube 74 falls, thus reducing the pressure within the bellows 44 so that the bellows head 46 is pushed downwardly by push rod 87 under the action of spring 90, which is seen in Fig. 4. This brings the valve 40 nearer to its seat, until such a time

as this gradual closing of the valve 40 produces an appreciable pressure drop which will result in the rapid closing of the valve 40 as described in connection with valve 80 of my copending application Serial No. 331,683, filed April 26, 1940.

In addition to the operation described in this earlier application I show the push rod 33, the valve 26 and its spring 27. The length of push rod 33 is such that the final rapid movement of the valve 40 in closing causes a slight downward movement of valve 26 against spring 27. This slight opening of valve 26 is sufficient to pass liquid refrigerant as rapidly as it comes through the hole 21, hence there will be no more flow of liquid refrigerant to the higher pressure box evaporator past the valve 62. The closing of valve 40 allows the compressor to quickly evacuate the bore 84 and begin pulling lower pressure refrigerant from the freezer evaporator 14 through the tube 100 and the passage 102 of union 101, lifting the check valve 62' in bore 103, while liquid flows through union 28 and tube 98.

It will now be seen that the box evaporator is isolated from the active part of the system by the closing of the valve 40 and by the lack of sufficient pressure to lift the valve 62. The compressor will continue to operate, pulling vapor from the freezer until the pressure within the bellows falls further, allowing the head 46 and the push rod 87 to fall under the action of the spring 90 until the switch 123 returns to its open position as seen in Fig. 4, stopping the operation of the system with all parts returned to their relative positions as seen in Fig. 1.

To facilitate evacuating and charging of the system, means is provided for locking the bellows head 46 in a position nearer the lower extremity of its travel or in a position nearer the upper extremity of its travel. The stamping 91 is so formed as to provide a tubular protection around the bellows, a spacer between the valve assembly 4 and the switch assembly 3, a support for mounting the entire assembly 2, several inwardly turned projections forming a stop at the extreme upward movement of the bellows head 46, and an opening 92 which serves as a fulcrum for the lever 93. This lever is forked to straddle the push rod 87 with ample clearance and is pivoted by a pair of rivets 94 to an upwardly extending lug on each side of the center of head 46. In order to retain the lever 93 in the position shown, the operator can with his thumb push the stirrup 95 to the right so that it is hooked over the projection 96 of the part 91. Conversely the lever 93 may be pushed downwardly to lift the bellows head 46 to a point near the upper limit of its travel and it may be locked in this position by pushing the stirrup 95 under the extension 96. In this position the compressor will evacuate both evaporators and all of the low-side connections.

In the normal automatic operation of the system the parts 93, 94, 95 and 96 have no function. They are provided for convenience in servicing and to allow manually setting of the control for continuous operation on the box evaporator 12, or for remaining continuously idle. The latter setting is obtained by lifting the lever 93 so as to compress the bellows to the cut-out point of switch assembly 3, then hooking the stirrup over the extension 96 and letting the bellows return to the point at which this holds it. If the lever 93 is lifted while the system is in operation only enough to allow the stirrup 95 to swing over the projection

96 we will have forced the valve 40 to close and the valve 26 to open thus artificially starting operation on the freezer. An additional lug such as 96 or a series of notches in the part 95 may be provided for locking the bellows head in any desired position.

The forked end of the lever 93 and its relation to the bosses on the bellows head may be seen in Fig. 2. The handle end of lever 93 is so designed that it may be inserted through the hole 92 in assembly and the retainer strap 95 is then assembled to the lever 93 by means of a cotterpin so that it is readily removable for disassembly.

In order to understand how it is possible to operate each of the evaporators at its desired pressure, say ten pounds in the freezer and thirty pounds in the box evaporator with F 12 as the refrigerant, it is necessary to understand more clearly than has been explained in any publication just how a capillary expansion device operates in a refrigerating system.

The elongated spiral passage formed between the part 20 and the bore 18, together with the continuation of this passage formed between the parts 19 and 20, operates in the same manner as a capillary tube, but the operation of capillary tubes has heretofore been commonly misunderstood. The fact is that a capillary passage, no matter how formed, will pass a much greater weight of liquid per hour than it will pass of the vapor formed from the same liquid. This comparison being made for a given pressure difference between the ends of the passage. The principle which makes a capillary tube or passage effective to pass liquid and not to pass vapor is that when there is no liquid ahead of the capillary passage the rate of vapor flow through the capillary passage is such a small percentage of the capacity of the compressor in pounds of refrigerant per hour that there will be a very rapid increase of pressure in the condenser and this will cause the condensation of refrigerant to supply liquid to the capillary passage again.

The rate of refrigerant flow in liquid form may be greater than the rate of vapor flow through a given capillary passage in the ratio of 2 or more to 1. This means that a capillary expansion device of a given cross-section, length and form will be usable under considerable variation of the conditions which affect the number of pounds of refrigerant per hour required to pass through the capillary device.

Since an expansion device of the capillary type acts to pass liquid refrigerant as rapidly as it is condensed, very much like a high side float valve, it will be understood that the capillary device has of itself no action of a pressure regulating nature. It is not the capillary expansion device which determines the pressure-temperature condition in the evaporator which it serves. The pressure at which an evaporator operates when fed with liquid by means of capillary expansion device is a function of three modifying characteristics, i. e., the displacement rate of the compressor which is drawing vapor from the evaporator; rate of heat entry to the evaporator, and the amount of liquid in the system. The two evaporators 12 and 14 are alternately connected with the same compressor and each evaporator retains its proper refrigerant charge, hence the variable in this case is the rate of heat entry to the respective evaporators. Evaporator 12 has a greater surface than evaporator 14 and is located in the larger and warmer portion of the refrigerator 13. This causes a more rapid evaporation of refrigerant in

the evaporator 12 than in the evaporator 14, hence evaporator 12 operates at a higher pressure than evaporator 14.

Some inventors have recognized the fact that the temperature of a capillary passage affects the rate of refrigerant flow through it and have attempted to utilize this effect in balancing the operation of two evaporators, but these same inventors have clung to the idea of having a portion of the capillary tube located outside of the cabinet and thermally associated with the suction tube. While it is desirable to have heat exchange between the warm liquid refrigerant and the cold vapor returning to the compressor, it is not desirable to have any portion of the capillary tube or passage exposed outside of the cabinet or to any high temperature.

Designers using capillary tubes and other capillary type expanders in refrigerating systems having encountered the difficulty of running an excessively high head pressure for a period after a start of the compressor, particularly where a portion of the capillary tube is exposed outside of the cabinet. After the system has operated for a short time under this excessive head pressure and the suction tube has become chilled the head pressure drops to normal.

The cause of this high head pressure at the start of a cycle will be understood in consideration of the correct theory of operation of these so-called capillary devices. Anything which causes vapor to enter the tube or to form within the tube will restrict the rate of liquid flow. If the tube is excessively warm any small amount of liquid which enters it and vaporizes causes vapor-lock, which effect has long been recognized in automotive engineering but has not been properly recognized in connection with the operation of capillary tubes and similar expansion devices in refrigerating systems.

The capillary expansion device illustrated in Figs. 1 and 3 is designed to be self-cooling by virtue of the fact that a part of the first liquid to pass through the hole 21 into the interior of core 19 expands and chills the core and its surrounding spirally convoluted tube. It will be noted in Fig. 4 that the liquid line 11 is arranged in counter-flow heat-exchange relationship with the suction tube 86. The liquid line 11 is not a capillary tube of such small diameter that it would of itself restrict the flow of vapor to the extent of causing enough pressure to produce condensation in the condenser 10. This tube is preferably somewhat smaller than the usual liquid line of ¼ inch outside diameter. For a household refrigerator the inside diameter of this tube 11 might be between 1/16 and ⅛ inch. While this is not small enough to act as a capillary restrictor it is small enough so that vapor will push liquid ahead of it in the tube instead of the vapor blowing past the liquid.

The object of this selection of a proper internal diameter of the tube 11 is to insure that any liquid formed in the condenser 10 or in the tube 11 will pass on to the fitting 16. On the other hand the inside diameter of the tube 11 should be large enough so that the velocity of liquid flow through it is not too high. This allowed time for heat exchange from the liquid in the tube 11 to the cold vapor in the tube 86 and avoids the difficulty which has been experienced due to vapor-lock in capillary tubes that are located outside of the refrigerated space. The liquid refrigerant is chilled before it reaches the capillary device and the liquid in the capillary device is further chilled by

evaporation of refrigerant within the core 19. At the start of operation the tube 86 will not have cooled, hence the liquid which first enters the expansion device will be rather warm and it might re-evaporate in the capillary passage and cause vapor-lock if an ordinary capillary tube were used. While I might employ a tube coiled around the core 19 instead of employing the tapered, corrugated tube 20, I prefer the latter for the reason that one thickness of metal provides two spiral capillary passages, one for flow outside of and upwardly around the spiral shell 20 and the other running downwardly between the spiral shell 20 and the core 19. This arrangement provides a further advantage of locating the outlet 21 of the capillary passage at the very beginning of the evaporator and within the capillary device itself without employing awkward return bends of a capillary tube within the evaporator itself. It will be understood that the chamber within the core 19 actually is the beginning of the evaporator, both during operation of the freezer and during operation of the warmer box evaporator, this being the first passage of great enough cross-section to allow the refrigerant to vaporize to a great enough extent to produce an appreciable amount of refrigeration.

The core 19 of the capillary or vapor-lock device is threaded into the body 5 and provided at its lower end with a hexagonal boss so that it can be removed with a socket wrench. When removed the spirally corrugated tube 20 will slip off toward the smaller end of the part 19 so that the corrugations of the part 20 are cleanable both inside and out. The corrugations stop short of the lower end of the part 20 so that this end may be made a tight fit on the tapered outer surface of the part 19 to prevent liquid refrigerant from entering between these two parts from the bottom. The filter 17 is cylindrical in form and so designed as to be longitudinally compressible. The filter is thus compressed between the parts 19 and 16 when the latter is tightened against its gasket.

The spirally corrugated capillary shell 20 is preferably made from a drawn tube which is rolled to form the thread, thus corrugating the wall in spiral form. The tube is tapered and this taper may or may not be present in the tube prior to the rolling operation. In this rolling operation or in a separate spinning or swaging operation the larger end of the tube is so formed that its inner surface is made an accurate fit upon the conical outer surface of the part 19 at 30. On the inside of the tube the spiral surface which contacts the part 19 likewise falls in the same cone. On the outside of the convolutions the surface of bore 18 which contacts the part 20 is a true cone. It will thus be seen that when the part 19 is screwed into place the spirally corrugated tube 20 will make contact with the part 19 in a complete ring at its larger diameter and in a narrow spiral for the balance of the length of the part 20. Only the tops of the corrugations will touch the wall of the chamber 18. As the part 19 is tightened in the body 5 the part 20 will be squeezed between the two tapered surfaces and forced into intimate contact with them. It will thus be seen that liquid refrigerant entering through the union 16 must first pass through the annular filter 17, then through the spiral passage between the parts 20 and the body 5, returning through the spiral passage between the parts 19 and 20 to the hole 21. The liquid has access to substantially the entire surface of

the filter 17 due to the fact that it is made to fit freely over the largest dimension of the hexagon end of the part 19, so that liquid can flow between the flats of the hexagonal boss and the inner wall of the filter. At the smaller end of the part 20 the rolled thread which forms the corrugations is allowed to run out the end, leaving a passage for the liquid to enter between the parts 19 and 20 after it has passed through the spiral passage on the outside of part 20. At the larger end of the cone the thread runs into an annular corrugation or bead 24 in the wall of the part 20. The periphery of the bead 24 does not contact the wall of the bore 18, thus permitting the flow of liquid between it and such wall. It will thus be seen that when the filter is disassembled for cleaning it will be possible to separate the part 20 by pulling it out of the chamber 18 and off of the core 19 so that it may be washed inside and out. When the part 20 is replaced over the member 19 it will not be necessary to register the thread with the hole 21 as at this point the annular bead 24 forms a continuous passage at an axial position which coincides with the hole 21.

It is proposed that the assembly 2 of Fig. 4, comprising the capillary and valve device 4, the switch mechanism 3 and the support 91, be produced as one assembly, bolted together so that the whole may be supported by the part 91, which is provided with screw holes for that purpose.

At the outlet end of the evaporator 12 is a small liquid accumulator 73, similar to accumulator 99 located at the outlet end of the freezer evaporator 14. These accumulators are for the purpose of allowing some variation of liquid volume in their respective evaporators. There will be a slight transfer of refrigerant from one evaporator to the other in both directions, causing a slight fluctuation of liquid volume in each evaporator.

Some refrigerant will be transferred from the warmer evaporator to the colder one after the compressor has stopped, due to the condenser emptying itself into the freezer evaporator. When the first refrigerant is pumped into the condenser at the start of the run it will come from the box evaporator. There may also be a slight leakage past the push rod 33 and past the valves 62 and 62'. These effects all tend to transfer refrigerant from the warmer to the colder evaporator.

An effect operating in a reverse direction is as follows. At the time the compressor stops there will be a pressure within its suction chamber equivalent to the lowest pressure ever existing in the colder evaporator. During the idle period there will be vapor flowing from the freezer past the valve 62' and into the suction chamber of the compressor. Since the sealed unit type of compressor is now the popular one and it is customary to have low pressure refrigerant vapor within the housing around the motor and the compressor, it will be seen that this type of motor-compressor unit has a suction chamber which is large enough to hold a considerable amount of refrigerant in vapor form. The amount of refrigerant which may thus be transferred from the freezer to the box evaporator will exceed the amount of refrigerant that is transferred from the box evaporator to the freezer in the event that the freezer contains slightly more liquid refrigerant than it should have. On the other hand in the event that the freezer evaporator is under-charged the amount of refrigerant which

will thus be transferred from the freezer to the box evaporator will be less than the amount that is transferred from the box evaporator to the freezer. These effects become automatically self-balancing in a properly designed system.

The valve seats 60 and 60' are identical, as are the disc valves 62 and 62', though it would be permissible to make the valve 62 and its seat 60 considerably smaller because it is only required to pass liquid at this point. The plug 70 is inserted in the passage 68, preferably with a light drive fit. While the passage 68 and the passage 22 might be made of the same diameter, I prefer to leave a shoulder for location of the plug 70 by making the passage 22 slightly smaller.

The push rod 33 is not attached to either the valve 40 or the valve 26. It fits very closely in a reamed hole in the body 5. Since the pressure in the passage 78 is the suction pressure of the box evaporator and the pressure within the bore 23 is part of the time the inlet pressure to the box evaporator and part of the time the inlet pressure to the freezer evaporator, it is apparent that there can be no great pressure difference between the passage 78 and the bore 23 to cause leakage around the push rod 33. There need be no leakage in the direction of reverse flow past the valves 62 and 62' since the seats 60 and 60' are removable for accurate lapping in production and it has been found that valves of this type will retain their tightness even in compressors and other applications where there is more heat and more pounding of the valve on its seat. These valves are retained by covers 64 and 64' which are soldered to the body 5. Each of these covers is provided with a downwardly extending point which acts as a valve stop.

The refrigerator 13 includes a separately insulated compartment 15, which is provided with a door of its own. The door of the larger compartment of the refrigerator 13 may also enclose the door of the compartment 15 if desired, but in any event we have two refrigerated compartments, each cooled by its own evaporator, and the compartment 15 is cooled to a lower temperature than the other compartment.

The stem of valve 26, which provides a guide in the removable seat member 25, is fluted like the stem 35 of valve 40, on which the flutes 37 are more readily seen.

The functions of the upper stem 41 of the valve 40, the spring 42, the hollow boss 48, the hole 50, and the smaller diameter pin 52 are explained in more detail in the co-pending application above referred to. It is necessary that the pin 52 have considerable clearance either in the hole 50 or in its fit in the stem of the valve 40. This clearance allows the bellows head 46 and the push rod 87 to continue in their downward movement after the valve 40 has been seated, thus allowing the switch 3 to function at its cut-out point. As the bellows is expanded during an idle period by an increase of pressure coming from the freezer this upward movement of the bellows head 46 weakens the compression on the spring 42 so that less pressure will be required in the passage 78 to open the valve 40. This effect is also explained in the earlier application to which I have referred.

The evaporator 12 is shown diagrammatically at one side of the box 13 in Fig. 4 to allow for showing the control device on a larger scale. It will be understood that the evaporator 12 is to be designed with a surface large enough to do the job of cooling the main food compartment of the refrigerator without need for having a great temperature difference between the air in the refrigerator and the evaporator 12. One preferred arrangement of the evaporator 12 is to wrap it about the liner of the cabinet, between the liner and the insulation so that the evaporator is not visible from the interior of the cabinet. Another preferred construction is to loop the coil 12 across substantially the entire rear inside wall of the cabinet, located against or adjacent to the inside of the liner and then hiding the coil by means of a shield. This shield may be considered as a baffle to induce air circulation over the coil, or it may be in thermal contact with the coil and thus provide an extended cooling surface for cooling the air within the main food compartment of the refrigerator.

Referring to Fig. 5 we see a modified form of the filter and capillary expander of Fig. 1. This view shows that portion of the body 5 which is modified from Fig. 1. The union 16' corresponds to the union 16 of Fig. 1. Valve disc 62 and its seat 60, the drilled holes 68 and 22 and the plug 70 serve the same purposes as in Fig. 1, the union 71 being the connection for the liquid line to the warmer evaporator as in Fig. 1. The drilled hole 66' leads to the lower side of the valve 62 and its seat 60 instead of leading from the upper side as does the drilled hole 66 in Fig. 1. The valve cover 64 is the same as in Fig. 1 except that it has a slightly longer pointed projection to form the valve stop. Plug 65 is added.

In Fig. 5 the filter and capillary device are located above the horizontal passages 22 and 68 instead of below as in Fig. 1. This location has an advantage in that practically all of the liquid refrigerant will pass through the filter and capillary device into the passage 22 at the end of a running period, thus avoiding the slight loss due to evaporation of liquid in the chamber 18 of Fig. 1 and the resulting passage of vapor into the lower temperature evaporator. The closure disc 65 is added to close the opening which must be left for drilling the hole 66'. The bore 18' is in an upwardly projecting boss of the body 5, replacing the bore 18 of Fig. 1. Within this bore is a stack 104 of filter discs and below these is a stack of capillary discs 105, the combined stack of discs being secured by means of the screw 120 and the washer 121. The discs comprising the filter portion 104 are not shown in detail but will be understood when described as an assembly of discs such as are commonly marketed in the United States by Zenith Carburetor Division of Bendix Aviation Corporation and briefly comprise a stack of perforated circular discs and alternate spoked or star-shaped members, the thickness of which determines the fineness of the filter. Liquid refrigerant entering the bore 18' through the union 16' enters slots in these filter discs, the discs being so thin that no particles of dirt large enough to cause trouble will enter the slots. The lowermost one of the discs comprising the filter stack 104 is so punched as to deliver liquid to the uppermost one of the discs comprising the stack 105. These latter discs forming the capillary passage are represented by Figs. 6 to 14, inclusive, these figures being numbered in the order that the discs are located from top to the bottom of the stack 105. It will be understood that there may be more than one set of the discs 6 to 13, inclusive, in the stack 105. Each alternative one of these discs is punched with a horse-shoe shaped slot 117 to form a passage and the discs above and below it are

punched with holes 118 to connect a pair of the discs which have the horse-shoe-shaped slots. Liquid refrigerant after passing through the filter discs passes successively through these horse-shoe-shaped slots which, in combination with the intermediate discs, form a continuous capillary passage from the filter to the lowermost disc, which is so punched as to deliver refrigerant into the passage 22. The entire assembly of filter and capillary discs may be removed for cleaning.

Figure 6 represents the disc 106 which may be assumed to be the uppermost one of the capillary stack 105, going next to the lower disc of the filter stack 104. The stack 105 consists of discs 106, 107, 108, 109, 110, 111, 112 and 113 in this sequence as shown by Figs. 6 to 13, inclusive. They are placed on the screw 120 in the order given and aligned with each other by means of the tongues 115, which can best be seen in Fig. 15. While the uppermost disc of the stack may be number 106, 108, 110 or 112 the lowermost disc will always be 113. The stack may be built up with several sets of discs or a certain number of sets plus a part of a set, but will always start with one of the discs which has the C-shaped slot 117 and will always finish at the bottom with the disc 113, which rests upon the larger disc 114. The disc 114 has a notch 116 cut out of it instead of having a tongue 115, thus the tongue 115 of the disc 113 will extend into the notch of the disc 114 and thereby be held in register with it. Similarly the tongue of the disc 112 will extend into the notch formed by shearing and downwardly bending the tongue 115 of disc 113, continuing thus to the uppermost disc of the capillary stack 105, which disc will be next to the lowermost filter disc of the stack 104. The bottom disc 114 is not only larger in diameter but preferably thicker than the capillary discs and is punched with the oval hole 119 to pass the screw 112 and to register with the hole 118 of disc 113 so that liquid refrigerant may flow into the passage 22 from the stack of capillary discs. In this manner the stack 105 of capillary discs may be built up to provide whatever length of passage is required, thus obtaining the desired restriction of refrigerant flow. This restriction need not exactly match each size of refrigerating system but must fall within a certain rather wide tolerance. The tolerance limit requirements are that the capillary passage must allow free enough flow so that liquid refrigerant will, under the minimum operating pressure difference between high and low sides of the system, pass at the maximum rate of liquid flow that can be obtained with the system on the application for which it is used. The other limit is that the rate of refrigerant vapor flow through the capillary stack 105 must be slower than the slowest rate at which vapor is moved by the compressor. The rate of flow in both the case of liquid and the case of vapor is calculated on the basis of pounds weight per unit of time.

Fig. 15 is shown as a section of Fig. 11 and at double size. This section is mainly to illustrate the tongue 115, which locks the capillary discs together against independent rotation. So far as the tongue 115 is concerned, Fig. 15 may be considered a section of any of the Figs. 6 to 13, inclusive.

The discs, Figs. 6, 8, 10 and 12, are identical except for the location of the tongue 115 relative to the C-shaped slot 117. Likewise discs, Figs. 7, 9, 11, and 13, are identical except for the location of the tongue 115 with reference to the hole 118. Since the discs are always used in the sequence given, and the discs having holes 118 alternate with the discs having the C-shaped slot 117, the production requirements will come out even on the discs 106 to 113, inclusive. This will simplify production of the discs by making it possible to use a gang die, punching out one or more of each disc at each stroke of the press, preferably from a roll or long strip of brass stock. The press may be equipped with a delivery mechanism which stacks the discs up in the order in which they are to be used, thus facilitating assembly of the stack 105 to the filter stack 104.

Without changing the die, but merely by substituting stock of a different thickness, it is possible to vary the size of the passage formed by the C-shaped slots 117. Thus if a greater degree of restriction is desired it is only necessary to use a thinner sheet of brass or to include more pieces in the stack 105. The total height of the stack 105 may be substantially the same for a large number of thin discs as for a smaller number of thicker discs, yet the two stacks will be adapted for use in refrigerating systems of widely different capacities.

It is not necessary that the filter be of Zenith type, as represented by the stack of discs 104. In place of this stack we might use one or more felt washers, as will be seen in Figs. 16 and 17.

Fig. 16 shows a filter and capillary assembly separately from the valve mechanism of Fig. 1, representing an assembly suitable for use in a refrigerating system employing only one evaporator or one having evaporators arranged in series. Liquid refrigerant enters through the union end of the body 130, passing through one of the screens 134, through the filter 136, through the second screen 134 and then through the stack 138 of capillary discs and the end disc 114' into the chamber 140 of the union end 132. The stack 138 comprises discs substantially as shown in Figs. 6 to 13, inclusive, except that the central holes are not required, the discs being held in place by their outside diameters instead of by a central screw as shown in Fig. 5. Likewise the disc 114' is the same as the disc 114, except that its outside diameter is the same as that of the balance of the capillary discs. In assembly, the screens, the filter material, the stack 138 and the disc 114' will be inserted in the body of the part 130. The union 132 will now be inserted as shown in Fig. 16 and the whole brazed or soldered together. The filter material 136 will preferably be of a compressible nature, but in any event the amount of filter material and the number of discs in the stack 138 will be so related to the parts 130 and 132 that when the assembly is squeezed together lengthwise there will remain a slight gap 142, which will be filled with solder or spelter as the external parts are sweated together.

Fig. 17 represents a modification of Fig. 16 in that there is a filter 136 with its screens 134 on each side of the stack 138 of capillary discs. Two of the ends 132 are shown in this view, each being sweated to a plain tubular body 141. This type of assembly is adapted for use in a system wherein the direction of refrigerant flow is required to be reversed through the capillary stack 138. Such an application will be seen in Fig. 9 of my Patent No. 2,145,773, issued January 31, 1939. It is desirable in this sort of system to have a filter on each side of the expansion device so that the capillary passages in the stack 138 will be kept free from foreign matter which might clog them up.

The parts 132 in Figs. 16 and 17 are formed with a smaller chamber 140, which allows some expansion of the refrigerant before it passes on to the evaporator. This will produce some cooling effect for the purpose of chilling the capillary stack 138, thus avoiding the vapor-lock difficulty before mentioned.

A further modification of the filter and capillary assembly is seen in Fig. 18. The body 144 is substantially a pipe coupling in which there is a dividing wall 145, having a central opening 146. In the inlet end of the body 144 is a stack 104 of filter discs, secured by means of the screw 147. This screw is located axially of the body 144 by means of the discs 148 on the outlet side of the wall 145. The screw 147 also secures a stack of capillary discs 105, as seen in Figs. 5 to 13, inclusive. Next to the head of screw 147 is a heavier disc 150, having a hole 151 located in register with the C-slot 117 or the hole 118 of the adjacent capillary disc. The locating disc 148 is shown in detail in Fig. 19. This disc is located in the body 144 by means of its outside diameter, very much as is the disc 114 in Fig. 5, but it must also serve to locate the screw 147, hence a central hole is employed instead of the oval hole 119 of Fig. 14. To provide a passage for refrigerant, an additional hole 118 is located in register with one of the holes identified by the same number in the adjacent capillary disc. The disc 148 is also provided with a notch 149 to receive the tongue 115 of the adjacent capillary disc. It will be noted that in Fig. 5 the direction of refrigerant flow is toward the disc 114 or in the direction in which the tongues 115 are bent, whereas in Fig. 18 the direction of refrigerant flow is away from the disc 148 or in the other direction from that in which the tongues 145 are bent. This makes no difference in the operation of the stack of capillary discs, as will be understood from Fig. 17, in which liquid refrigerant flows part of the time in one direction and part of the time in the reverse direction through the stack 138 of capillary discs.

The filter material of 136 in Figs. 16 and 17 is preferably such that it may be slightly compressed in assembly and will retain a springy action sufficient to hold the discs of the capillary stack 138 tightly together after long use. In the event that it is not desired to use a material having this characteristic, a separate spring may be provided to insure continued tightness. Such a spring 153 is illustrated in Fig. 18. This spring will not be required when the filter stack 104 is employed, but might in some cases be desirable in the event of substituting fibrous washers such as employed in Figs. 16 and 17.

In referring to the discs 106 to 113, inclusive, as forming a "capillary" passage it should be noted that the restriction is due not only to the capillary action of the passages 117 but to the orifice action of the holes 118. In the event that the passages 117 are increased in size and the holes 118 reduced in size the action will be substantially that of a series of orifices. If, on the other hand, the holes 118 are made quite large and the discs in which are formed the passages 117 are made quite thin the restriction will be mainly due to the small section of the passages 117. It is to be understood that the design may be varied in this manner without departing from the spirit of this invention.

In some cases it may be desired to provide a greater amount of restriction for the flow of liquid refrigerant to the colder evaporator. Such

a modification is illustrated in Fig. 20, wherein the location of the check valve 62 is changed from that shown in Fig. 1. The stop for check value 62 becomes 64' as it has a longer stem like the stop 64' seen in Fig. 1. The change of location of the check valve is to provide for less restriction of that portion of the liquid refrigerant which flows to the warmer evaporator. This is taken off at the top of the spirally corrugated shell 20, thus being required to pass through only that portion of the capillary passage which is formed between the part 20 and the wall of chamber 18, whereas that portion of the liquid passing through the hole 22, as in Fig. 1, to the freezer evaporator must also flow through the capillary passage between the parts 10 and 20. The drilled hole 67 of Fig. 20 provides a passage for liquid refrigerant from the space at the top of part 20 to the check valve 62 and thence to the passage 68. The drilled hole 67 is closed by the plug 69. It will be obvious that this method may also be applied to the type of capillary device illustrated by Figs. 5 to 18, inclusive.

As will be understood from the foregoing description I use the term "vapor-lock" to designate that type of refrigerant expansion device which operates on the vapor-lock principle. This general term includes both the so-called "capillary" expansion devices and the orifice type of expansion devices, whether the refrigerant passes through only one fixed orifice or several, as well as to devices which combine these two methods of refrigerant control, as shown in Figs. 5 to 19 of the accompanying drawings.

Many combinations not shown by the drawings will be obvious from them in connection with this specification. For instance any type of filter might be employed in connection with any of the vapor-lock devices. Also the capillary devices of Figs. 5 to 18, inclusive, might be used in Fig. 1, or in Fig. 20 by providing a separate outlet by means of a special disc located in the stack of refrigerant control discs.

Another variation is to change the order of assembly of discs in the stack 105 so that the liquid reverses its direction of flow around the axis of 105 in each of the slotted discs. One such variation is to arrange them in this order: 106—107—106—113—106—107—106—113—106—etc., ending with 113—114 or with 113—148. This does not require the parts shown by Figs. 8, 9, 10, 11 and 12. The tongue 115 may, for this arrangement, be formed in part 106 between the ends of the slot 117, in part 107 in a position 45 degrees clockwise from hole 118 and in part 113 in a position 45 degrees counter-clockwise from hole 118, thus allowing for making the discs smaller in diameter. A similar arrangement is also usable in Fig. 16, ending with 114'. In Fig. 17 the same is true, except that the disc 114' is not used.

What is claimed is:

1. In a refrigerating system, a vapor-lock expansion device comprising a shell helically corrugated to form both male and female threads, a body member externally contacting said threads, and a core member placed within said shell.

2. In a refrigerating system, a pair of evaporators, a pair of valves in mechanically opposed relationship, one of said valves controlling a suction passage leading from one of said evaporators and the other of said valves controlling liquid refrigerant flow to the second of said evaporators, refrigerant flow control means controlling the flow of refrigerant to said second of said valves, the connection between said valves being so con-

structed and arranged that the closing of one valve causes the opening of the other, and means for operating said valves for the purpose of controlling the selective cooling of said evaporators, one evaporator being designed to operate at a lower pressure than the other.

3. A refrigerant control device for use in a refrigerating system comprising, in combination, a spirally corrugated shell, a female part into which said shell is fitted, and a male part fitting within said shell, the spiral passages thus formed between said shell and parts serving as refrigerant flow passages and being of such size and form that they are capable of passing liquid refrigerant at a higher rate than it is condensed in said system but not of passing the vapor of said refrigerant at as high a rate as it is compressed in said system.

4. In a refrigerating system, a pair of evaporators connected in parallel, a pair of insulated enclosures to be cooled by said evaporators, said evaporators and said enclosures being so constructed and arranged that one of said evaporators will operate at a lower suction pressure than the other, a refrigerant flow control device, a liquid supplying connection and a suction connection between each of said evaporators and said control device for supplying liquid refrigerant to and returning refrigerant in vapor form from said evaporators, a check valve in the liquid supplying connection between said control device and the warmer evaporator, a check valve in the suction connection from the outlet side of the colder evaporator, a positively actuated valve in the liquid supplying connection between said control device and the colder evaporator, a positively actuated valve controlling the outlet of vapor from the warmer evaporator, and a common actuating means for the last two-mentioned valves.

5. In a refrigerating system, a plurality of evaporators designed to operate at different temperatures, valve means enclosed within said system for controlling refrigerant flow to selectively refrigerate said evaporators, an expansible member exposed on one side to refrigerant pressure within said system and exposed on its opposite side to atmosphere, external manually operable means connected through said expansible member to said valve means for the purpose of manually opening a valve to provide for evacuating the entire low pressure side of said system including both of said evaporators, and refrigerant flow control means through which refrigerant is fed to said valve means.

6. In a refrigerating system, a pair of evaporators, control means for causing said evaporators to operate at different times and temperatures, means for compressing refrigerant vapor, and means for substantially equalizing pressures on the opposite sides of said compressing means during idle periods thereof, said control means including means causing each of said evaporators to retain some liquid refrigerant during its idle periods and to start and stop said periods in response to changes of vapor pressure above said retained liquid.

7. In a refrigerating system, a pair of evaporators, vapor-lock means for regulating the flow of refrigerant to said evaporators and comprising the sole pressure reducing device for each said evaporator, and means for causing selective operation of said evaporators and for retaining liquid refrigerant in an idle evaporator, said selective means being responsive to a drop of pressure in either evaporator to stop its operation and to a rise of pressure in either evaporator to start its operation.

8. In a refrigerating system, a pressure imposing element, a condenser, an evaporator, a space refrigerated by said evaporator, a high pressure liquid refrigerant conduit connected with the outlet of said condenser, a low pressure refrigerant vapor conduit connected with the outlet of said evaporator, portions of said two conduits forming a heat exchange section located outside of said refrigerated space, and a fixed restrictor connecting the outlet of said high pressure conduit with the inlet of said evaporator, said high pressure conduit having an inside diameter larger than any diameter that would cause a substantial drop of pressure at the required rate of flow through it and the upwardly directed portion thereof having an inside diameter smaller than any diameter that would allow vapor and liquid to pass each other therein.

9. In a refrigerating system, an evaporator, a space cooled by said evaporator, a high pressure liquid refrigerant conduit, a fixed restrictor connecting said conduit to said evaporator, a low pressure refrigerant vapor conduit, and a heat exchange section including portions of said conduits located outside of said cooled space, the inside diameter of that part of said liquid conduit which is in heat exchange with said vapor conduit being greater than one sixteenth inch and less than one eighth inch.

10. In a refrigerating system, a condensing unit, an evaporator, a space cooled by said evaporator, a refrigerant flow controlling device of the vapor-lock type connected to supply liquid refrigerant to said evaporator, a high pressure refrigerant conduit connected to supply liquid refrigerant to said flow controlling device, a low pressure refrigerant vapor conduit leading from said evaporator, and a heat exchange section including a portion of each of said conduits insulated from said cooled space, said liquid conduit up to and including the portion in heat exchange with the vapor conduit having an inside size great enough to allow refrigerant to flow therethrough with a negligible drop of pressure, said liquid conduit also being small enough to prevent liquid and vapor passing each other therein.

11. In a refrigerating system, an evaporator, a space cooled by said evaporator, a refrigerant flow controlling device of the vapor-lock type connected to supply liquid refrigerant to said evaporator, a high pressure refrigerant conduit connected to supply liquid refrigerant to said flow controlling device, a low pressure refrigerant vapor conduit leading from said evaporator, and a heat exchange section including a portion of each of said conduits insulated from said cooled space, said liquid conduit up to and including the portion in heat exchange with the vapor conduit having an inside diameter greater than one sixteenth inch and less than one eighth inch in that portion which is in heat exchange with said vapor conduit.

12. In a refrigerating system, a pair of evaporators operating at different temperatures, a refrigerant flow controlling device operable to produce said temperatures and including a liquid control of the vapor-lock type comprising the sole pressure reducing means in said system, said vapor-lock device including means for cooling it in advance of the cooling of said evaporator, a refrigerant conduit conveying high pressure liquid refrigerant to said flow controlling device at

a substantially constant pressure throughout its length, a refrigerant vapor conduit leading from said evaporator, and heat exchange means including a portion of each of said conduits.

13. In a refrigerating system, a pair of evaporators, a liquid conduit leading to each of said evaporators, a suction conduit leading from each of said evaporators, refrigerant fluid flow control means of the vapor-lock type arranged to feed liquid refrigerant to said evaporators one at a time, valve means controlling both the liquid and suction conduits of each of said evaporators, said valve means serving to retain refrigerant in both liquid and vapor phase in each of said evaporators during idle periods thereof.

14. In a refrigerating system, an expansion device of the vapor-lock type, a pair of evaporators arranged to operate at different times within different temperature limits, each receiving liquid refrigerant through the same rate-of-flow-regulating portions of said expansion device, and valve means for retaining a quantity of liquid refrigerant in the warmer one of said evaporators while it is idle and the colder evaporator is active.

15. In a refrigerating system, a pressure imposing element, a vapor-lock refrigerant flow control device, a plurality of evaporators connected in parallel in said system and served in common by said device, said vapor-lock device being the only means for reducing pressure upon liquid refrigerant between said pressure imposing element and said evaporators, and valve means between said vapor-lock device and each said evaporator for directing refrigerant flow through said evaporators selectively, liquid refrigerant going to each of said evaporators flowing through the entire length of the same passage of said vapor-lock device.

16. The method of regulating liquid refrigerant flow to first and second evaporators of a refrigerating system one at a time and causing evaporation of refrigerant to occur within a range of relatively low temperatures in the first evaporators and within a range of relatively higher temperatures in the second evaporator, comprising the steps of imposing vapor-lock restriction on the refrigerant by causing it to flow through a restricted passage of fixed proportions and thereby reducing the pressure on the refrigerant as it enters the first evaporator, then causing refrigerant to change its path of flow to enter the second evaporator and evaporate therein within the range of relatively higher temperatures while continuing to flow through all of the same restricted passage.

17. In a refrigerating system, a pressure imposing element, an evaporator arranged to operate at a low temperature, a second evaporator arranged to operate at a higher temperature, and a refrigerant flow controlling device of the vapor-lock type serving as the sole liquid rate of flow regulating means for refrigerant flowing to either of said evaporators and using its entire flow restricting means for controlling flow to each of them, said system being so constructed

and arranged and containing such a quantity of refrigerant that substantially no liquid refrigerant is trapped in the high pressure portion of said system at any time and all liquid drains to the low pressure portion of the system in liquid phase during each idle period.

GLENN MUFFLY.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,643,179	Sawyer	Sept. 20, 1927
1,728,183	King	Sept. 17, 1929
1,782,689	Hoffman	Nov. 25, 1930
1,795,872	Maccabee	Mar. 10, 1931
1,842,529	Maccabee (2)	Jan. 26, 1932
1,928,695	King (2)	Oct. 3, 1933
1,947,929	Emanueli	Feb. 29, 1934
1,953,433	Replogle	Apr. 3, 1934
1,990,663	Muffly (2)	Feb. 12, 1935
2,021,079	Mittendorf	Nov. 12, 1935
2,022,771	Killen	Dec. 3, 1935
2,038,153	Williams	Apr. 21, 1936
2,038,198	Replogle (2)	Apr. 21, 1936
2,042,462	Hahn	June 2, 1936
2,045,810	Tweedale	June 30, 1936
2,049,413	Cannon	Aug. 4, 1936
2,062,857	Askin	Dec. 1, 1936
2,063,496	Evers	Dec. 8, 1936
2,063,745	Kucher	Dec. 8, 1936
2,065,596	Maccabee (3)	Dec. 29, 1936
2,071,935	Muffly (3)	Feb. 23, 1937
2,089,961	Hull	Aug. 17, 1937
2,118,290	Black	May 24, 1938
2,118,295	Crawford et al.	May 24, 1938
2,128,020	Smilack	Aug. 23, 1938
2,133,948	Buchanan	Oct. 25, 1938
2,133,949	Buchanan	Oct. 25, 1938
2,133,950	Buchanan (2)	Oct. 25, 1938
2,133,951	Ashbaugh	Oct. 25, 1938
2,133,952	Buchanan (3)	Oct. 25, 1938
2,133,953	Buchanan (4)	Oct. 25, 1938
2,133,955	Buchanan (5)	Oct. 25, 1938
2,133,956	Buchanan (6)	Oct. 25, 1938
2,133,959	Buchanan (7)	Oct. 25, 1938
2,133,960	McCloy	Oct. 25, 1938
2,133,961	Buchanan (8)	Oct. 25, 1938
2,133,962	Shoemaker	Oct. 25, 1938
2,133,963	McCloy (2)	Oct. 25, 1938
2,133,968	Van Selver et al.	Oct. 25, 1938
2,133,964	Buchanan (9)	Oct. 25, 1938
2,133,966	Buchanan (10)	Oct. 25, 1938
2,139,110	Boles	Dec. 6, 1938
2,141,459	Bronaugh et al.	Dec. 27, 1938
2,145,774	Muffly	Jan. 31, 1939
2,165,518	Stolz	July 11, 1939
2,183,343	Alsing	Dec. 12, 1939
2,183,346	Buchanan (11)	Dec. 12, 1939

FOREIGN PATENTS

Number	Country	Date
218,231	Germany	Dec. 24, 1914
164,550	Germany	Nov. 2, 1905