

Aug. 4, 1942.

G. I. HOLMES

2,291,898

EXPANSION VALVE

Filed May 5, 1939

3 Sheets-Sheet 1

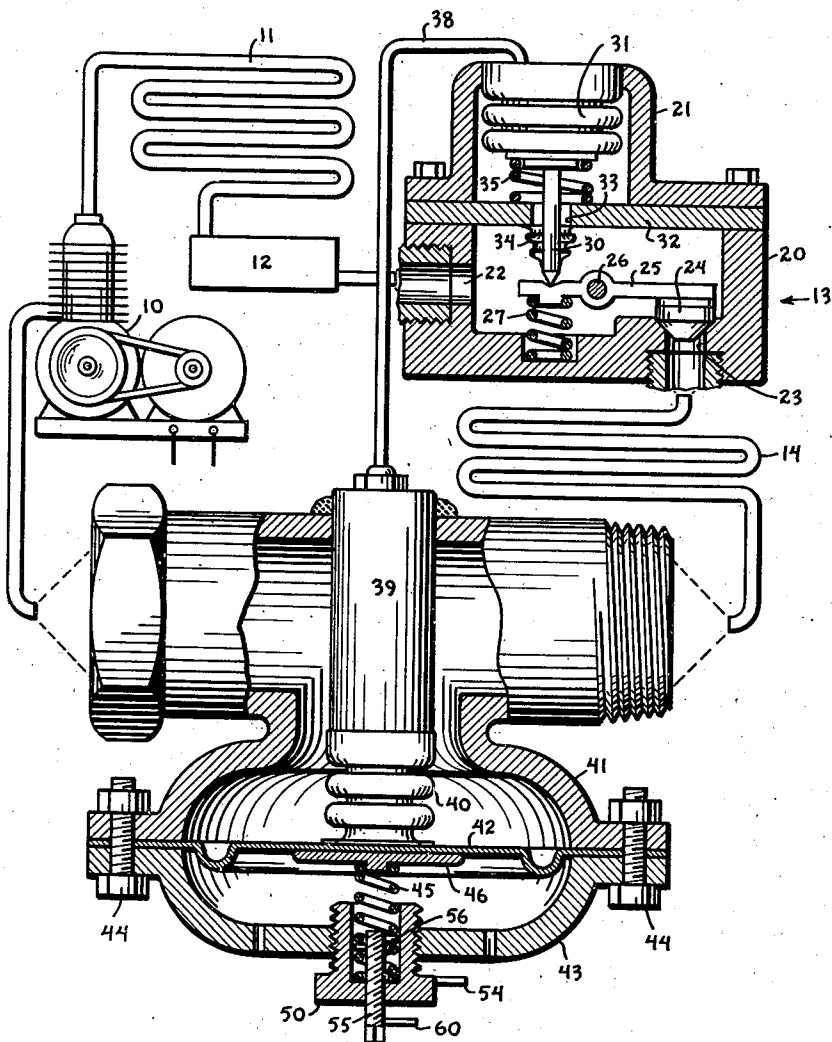


Fig.1

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3 Sheets-Sheet 2

Fig. 2

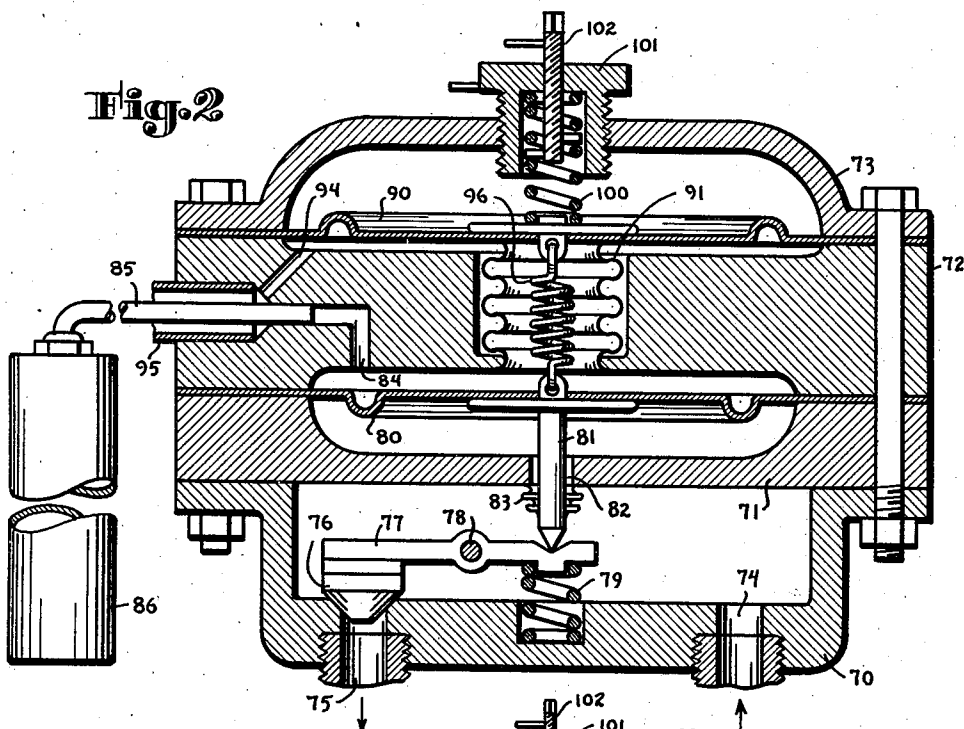
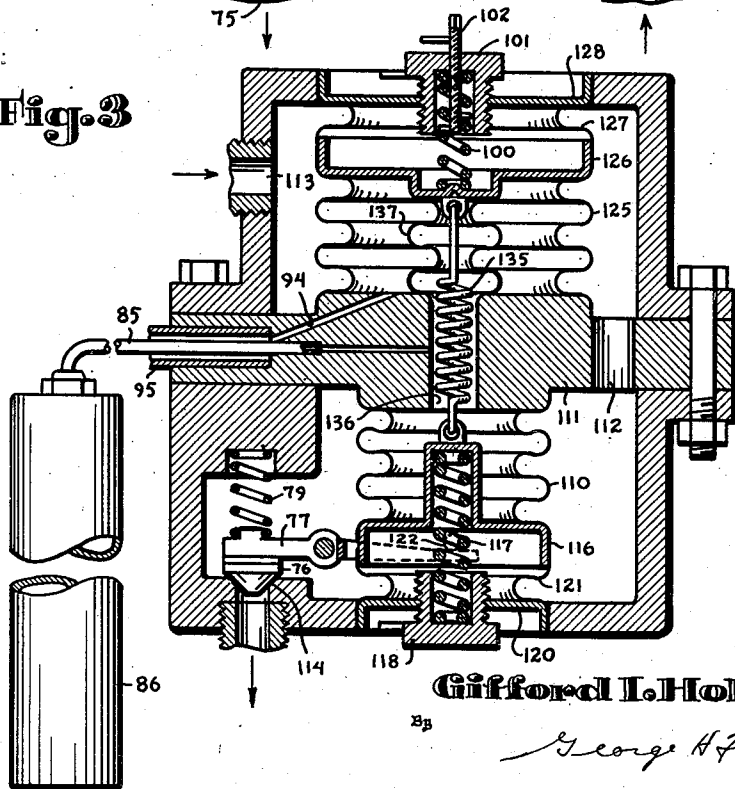


Fig. 3



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3 Sheets-Sheet 3

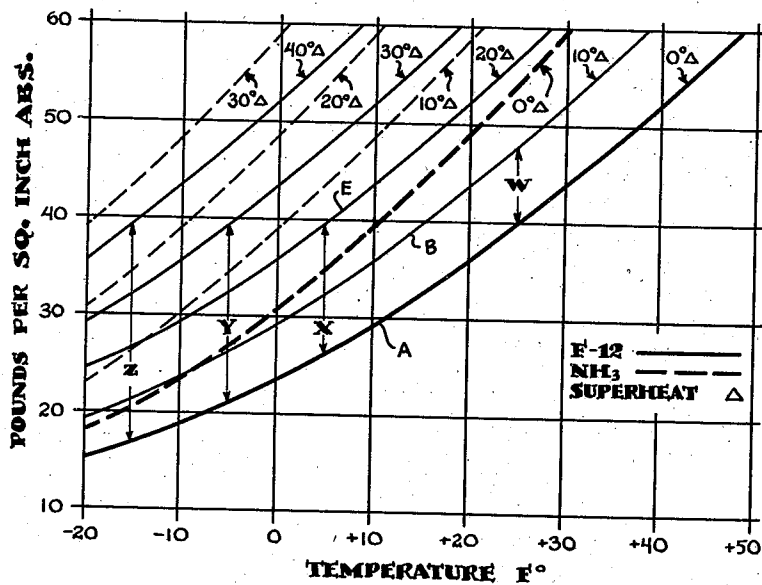


Fig. 4

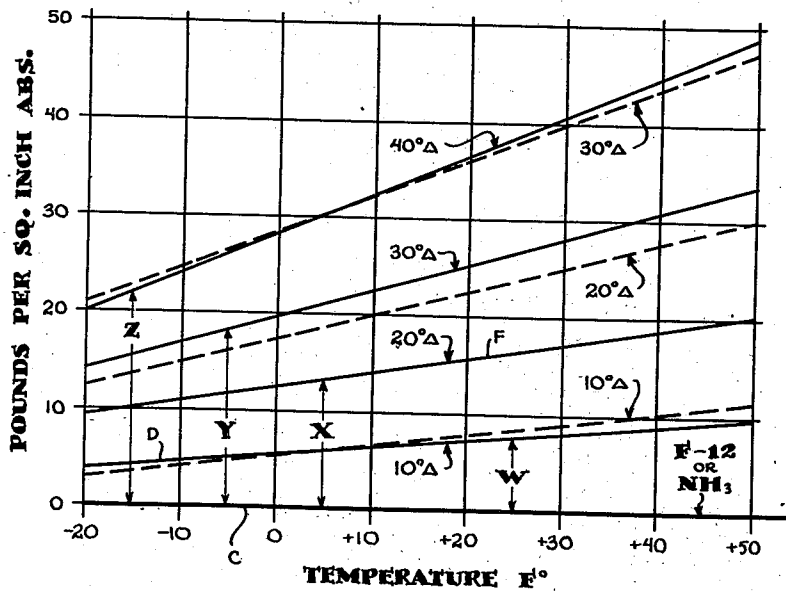


Fig. 5

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UNITED STATES PATENT OFFICE

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EXPANSION VALVE

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Application May 5, 1939, Serial No. 271,983

18 Claims. (Cl. 62-8)

This invention relates to expansion valves and more particularly to that type of valve known as thermostatic expansion valves such as are commonly employed in refrigerating systems.

One of the objects of this invention is the provision of an improved thermostatic expansion valve of the type which controls the flow of refrigerant through the evaporator in a manner to maintain the refrigerant at the outlet of the evaporator at a substantially constant degree of superheat.

More specifically it is an object of this invention to provide a thermostatic expansion valve and operating means therefor whereby the valve will control the refrigerant through the evaporator in such a manner that, regardless of variations in temperature and pressure, the refrigerant at the evaporator outlet will be maintained at a substantially constant degree of superheat, with means for adjusting the superheat setting of the valve without affecting the ability of the valve to maintain the refrigerant at a substantially constant degree of superheat as the temperature and pressure of the refrigerant vary, at the new superheat setting of the valve.

A further object of the invention is the provision of a thermostatic expansion valve and operating mechanism therefor whereby the valve will remain closed whenever the temperature of the refrigerant at the outlet thereof drops to a predetermined value, regardless of the pressure existing on the suction side of the refrigeration system, whereby under light loads of the refrigeration system a better control of the humidity may be effected, as will be more fully explained hereinafter.

Other objects and advantages of this invention will become apparent upon a study of the specification, claims and appended drawings wherein like reference characters represent like parts in the various views and wherein,

Figure 1 is a view of one form of expansion valve and operating mechanism therefor shown in a conventional refrigeration system, with certain parts shown in cross section,

Figure 2 is a modification of the valve and operating mechanism therefor in Figure 1 shown in cross section,

Figure 3 is a cross sectional view of a still further modification of the valve and operating mechanism of Figure 1, and

Figures 4 and 5 are views illustrating the temperature pressure curves of two well known refrigerants.

In the past, expansion valves for controlling the

flow of refrigerant through an evaporator comprised an operating bellows or diaphragm which responded to the temperature of the refrigerant within the evaporator for controlling the position of the valve, the operating bellows or diaphragm opening the valve upon an increase in temperature or upon a decrease in pressure. The bellows or diaphragm also responded to the pressure on the suction side of the system, the pressure being taken at the inlet of the evaporator but the valve did not properly respond to the superheat of the refrigerant at the evaporator outlet because of the pressure drop existing within the evaporator, particularly on systems using a relatively large or multiple coil type of evaporator, the pressure drop being variable depending upon the load on the evaporator, so in order to make the valve properly respond to the superheat at the evaporator outlet a connection known as an equalizer connection was provided between the outlet of the evaporator and the operating bellows or diaphragm so that the bellows or diaphragm properly responded to the pressure at the evaporator outlet. This arrangement while satisfactorily controlling the valve according to the superheat at the evaporator outlet, did not act to maintain the superheat at a fixed value as the temperature and pressure of the refrigerant leaving the evaporator varied, so that the effective cooling area of the evaporator, or that portion thereof which was in a flooded condition would vary as the temperature and pressure of the refrigerant leaving the evaporator varied.

Upon reference to Figure 4 it will be seen why such valves would not properly maintain the superheat of the refrigerant leaving the evaporator at a constant value. Curve A shows the pressure temperature curve for the refrigerant Freon or F-12. It will be noted that this curve is not a straight line. Curves for all known refrigerants have the same characteristics as this curve for Freon. As the temperature of the saturated refrigerant increases, the pressure which corresponds to this saturated temperature increases at a somewhat faster rate. Thus as the temperature increases from -20°F. to -10°F. the pressure increases from approximately 15 lbs. to approximately 18 lbs. per square inch or in other words, the increase in pressure over this range is about 3 lbs. per square inch. On the other hand, as the temperature of the refrigerant increases from 20°F. to 30°F. the pressure corresponding to this temperature increases from approximately 36 lbs. to 44 lbs. per square inch; or in other words, for this 10° rise in tem-

perature the pressure increases by approximately 8 lbs. In the conventional thermostatic expansion valve a spring is employed which opposes the action of the power or operating bellows or diaphragm; or in other words, tends to close the valve against the opening force exerted thereon due to a rise in temperature. These springs generally exert a substantially constant force upon the valve and may be adjusted to maintain a certain degree of superheat of the refrigerant at a given value of temperature, for example: Assume that it is desired to maintain a 10° superheat of the refrigerant at the evaporator outlet when the suction pressure is 35 lbs. The temperature of the saturated refrigerant corresponding to this pressure will be approximately 18° F. as will be noted from curve A of Figure 4. If the refrigerant is to be maintained at a 10° superheat the temperature of the refrigerant should be 28° and the pressure corresponding to this temperature will be approximately 43 lbs. Accordingly the spring which opposes the opening of the valve exerts a force equal to the difference of the 35 lbs. suction pressure and the 43 lbs. pressure which corresponds to the pressure of the saturated refrigerant at the higher temperature, or in other words, a force equal to 8 lbs. As the temperature gradually decreases at the outlet of the evaporator the superheat will gradually increase as explained below. Assume that the pressure at the outlet of the evaporator drops to 20 lbs., the temperature of the saturated refrigerant at this pressure will be approximately -7° F. and if the spring continues to exert an 8 lb. closing force the pressure corresponding to the temperature of the refrigerant will be approximately 28 lbs. and the temperature of saturated refrigerant corresponding to 28 lbs. pressure is approximately 8° F. Thus the superheat of the refrigerant leaving the evaporator at this lower pressure will have risen from 10° F. to approximately 15° F. At this lower pressure therefor the refrigerant will be in a greater state of superheat, less of the evaporator will be in a flooded condition, so that while the evaporator is operating at a lower temperature, the effective cooling surface thereof has decreased.

The curve B shows the constant 10° superheat curve and the vertical distance W between the curves A and B shows the actual closing force that should be exerted on the valve at varying temperatures and pressures in order that the superheat existing at the outlet of the evaporator will at all times be constant. This curve B it will be noted has a curvature somewhat similar to the curve A but gradually diverging therefrom as the temperature increases and if the curve A be taken as the base line, as shown by the line C of Figure 5, and the curve B plotted from this line, as shown by the line D of Figure 5, it will be seen that the line D is also a straight line. In order for the valve to operate along the line D of Figure 5 which is the constant 10° superheat line, the areas of the bellows or diaphragm which responds to the temperature of the refrigerant may be made slightly smaller than the area of the bellows or diaphragm responding to the pressure, as disclosed in the application Serial No. 192,818 filed by A. B. Newton on February 26, 1938. By choosing the proper relative sizes of the bellows or diaphragms responding to pressure and temperature and by choosing the proper spring to bias the valve towards closed posi-

tion the valve may be made to operate at the desired degree of superheat. This is done simply by properly proportioning the bellows or diaphragm areas.

The 20° superheat line is represented in Figure 4 by the reference character E and this curve has been transposed to Figure 5 and appears as the line F by marking off the distance marked X between curves A and E of Figure 4, in Figure 5. This line also appears as a straight line but has a somewhat steeper slope than the line C of Figure 5. In valves employing operating bellows or diaphragms having different sized areas as shown in the Newton application hereinbefore identified, if the force exerted by the spring is increased, the superheat line in Figure 5 would be above the line D of Figure 4 but since the spring rate would be the same as before the superheat line would be parallel with the line D of Figure 5 and if this line were transposed on to Figure 4 it would illustrate that the valve would not maintain the superheat at a constant value for varying pressures and temperatures. The amount that the superheat would vary from the desired value would increase as the spring was adjusted from the proper setting for which the valve was designed. However if the original loading of the spring and the spring rate are both properly varied the valve will maintain the superheat curve, if 20° superheat is desired, along the line F. This is one of the features of the present invention. Thus, increasing the spring loading would move the line D, Figure 5, upwardly parallel with itself, and increasing the spring rate would change the inclination of the line, so that by properly changing the spring rate for 20° superheat, the inclination and position would be changed to that of line F. The remaining full line curves of Figure 4 illustrate the 30° and 40° superheat curves, which curves also appear as straight lines in Figure 5, but these lines have increasing inclinations as the amount of superheat increases. Similar curves for the refrigerant ammonia are illustrated by dotted lines, the saturated ammonia curve of Figure 4 coinciding with the line C of Figure 5. In this figure it will be noted that the superheat lines appear as straight lines in the same way as the superheat lines for the refrigerant F-12.

Referring now to Figure 1, a refrigeration system is illustrated and is shown to comprise a compressor 10, a condenser 11, a receiver 12, expansion valve 13, and evaporator 14 connected together in conventional manner. The valve 13 controls the flow of refrigerant through the evaporator 14 and this valve is shown to comprise a casing composed of a lower section 20 and an upper section 21. The section 20 includes an inlet opening 22 through which high pressure refrigerant flows and the outlet opening 23 controlled by the valve element 24. This valve element may be suitably supported within the casing section 20 and is shown to be connected to one end of a lever 25 pivoted at 26 and having the opposite end engaged by the compression spring 27 which acts to bias the valve towards closed position. The position of the lever 25 is controlled by the plunger 30 suitably connected to the bellows 31 mounted in the upper casing section 21. A partition 32 separates the two portions of the casing and this partition has an opening 33 through which the plunger 30 extends, there being a suitable sealing bellows 34 for preventing escape of refrigerant into the

upper portion 21 of the casing. A spring 35 opposes the expansion of the bellows 31 and tends to permit closing of the valve under the influence of the spring 27.

The bellows 31 is in communication by means of the capillary tube 38 with a bulb 39 located within the evaporator outlet, this bulb 39 having an expansible portion in the form of a bellows 40 for a purpose to be described. The portion of the evaporator within which the bulb 39 is mounted has an enlarged portion 41 which forms a chamber for the diaphragm 42 which may be suitably clamped between the enlarged portion 41 and the cover member 43 by means of the bolts 44. The diaphragm 42 is sealed to the lower portion of the bellows 40 and this diaphragm is normally biased upwardly by means of the compression spring 45 held between the spring retainer 46 fastened to the lower portion of the diaphragm and the recessed adjusting screw 50 which is adjustably received by the cover member 43.

As the pressure of the refrigerant leaving the evaporator increases, the diaphragm 42 will be forced downwardly against the force of the spring 45 and this movement of the diaphragm will cause an expansion of the bellows 40 forming the lower end of the bulb 39 which will have the effect of increasing the volume of this bulb. The bulb 39, tube 38, and bellows 31 may be provided with a suitable liquid fill which will have a substantially constant volume as long as the temperature at the bulb 39 remains constant, so that as the volume of the bulb 39 increases, the bellows 31 will collapse by an amount corresponding to the increase in volume of the bulb. This action of the bellows 31 will permit the valve 24 to move towards closed position under the influence of the spring 27, thereby reducing the flow of refrigerant into the evaporator and causing a reduction in pressure therein. On the other hand, if the pressure of the refrigerant should decrease at the evaporator outlet, diaphragm 42 will move upwardly, collapsing bellows 40 which reduces the volume of bulb 39, and bellows 31 will expand a corresponding amount, thus causing an opening movement of valve 24, which increases the flow of refrigerant into the evaporator. It will thus be seen that the fill in the bulb, tube, and bellows acts as a hydraulic transmission means to transmit movements of the diaphragm 42 into movements of the bellows 31.

If now the temperature of the refrigerant leaving the evaporator should increase, there will be an expansion of the liquid fill in the bulb 39 which will cause an expansion of the bellows 31 and an opening movement of the expansion valve. Conversely, upon a decrease in temperature of the refrigerant leaving the evaporator, the volume of the liquid within the bulb 39 decreases, whereupon the bellows 31 will collapse in accordance with this decrease in volume, and the valve 24 will move towards closed position under the influence of spring 27, thus reducing the flow of refrigerant to the evaporator. It should be noted that the area of the diaphragm 42 which responds to the pressure of the refrigerant leaving the evaporator is considerably larger than the area of the bellows 31 which responds directly to the temperature of the refrigerant and also moves in accordance with the change in pressure by reason of the expansion or contraction of the bellows 40 and these relative areas will be so chosen that for a given set-

ting of the spring 45, that is, a given loading and spring rate, the valve 24 will move in a manner to maintain a constant superheat at the outlet thereof. Thus with the parts adjusted as shown in the drawings it may be assumed that the valve is adjusted to maintain a superheat of 10° using the refrigerant F-12 so that the valve will control the refrigerant according to the curve B of Figure 4 or curve D of Figure 5.

The adjusting screw 50 is for the purpose of adjusting the initial loading of the spring and this screw may be provided with a suitable pointer 54 which may cooperate with suitable indicia on the cover 43. Threadedly received by the screw 50 is an adjusting screw 55 having suitable stop members 56 which serve as abutment members for those coils of the spring which are located between the members and the diaphragm 42. By reason of the adjustment of the screw 55, the abutment members 56 move towards or away from the diaphragm 42 without changing the force of the spring 45 but by increasing or decreasing the number of turns between the members and diaphragm the effective length of the spring and the spring rate thereof may be adjusted. This adjusting screw 55 may be provided with an indicator 60 cooperating with suitable indicia on the head of the screw 50 so that the proper adjustment of screw 55 may be made for any superheat setting of the valve. Accordingly if it is desired to increase the superheat setting of the valve from 10° to 20°, for example, the adjusting screw 50 will be turned until the indicator 54 has moved to the proper position wherein the loading of the spring 45 has been increased the proper amount. The adjusting screw 55 will also be adjusted until the indicator 60 has moved to the position corresponding to the adjustment of the member 50 whereupon the spring rate has been increased the proper amount and the valve is now properly adjusted to maintain the refrigerant leaving the evaporator at a constant degree of superheat, namely, 20° F. regardless of normal fluctuations in temperature and pressure. By adjusting the spring rate of the spring, the line D was tilted upwardly until it was parallel with the line F and the change in the spring loading moved the line upwardly until it coincided with the line F, which line corresponds to the 20° constant superheat line E of Figure 4.

In the conventional type of expansion valve, employing a diaphragm responding to the superheat at the evaporator outlet, directly connected to the valve element, and having a spring opposing movement of the diaphragm in valve opening direction, the valve element will assume a predetermined position for each position of the diaphragm. In such an arrangement, if the spring rate of the spring were adjusted, the only effect upon the operation of the valve would be to change the operating differential thereof. A change in the loading of the spring would change the amount of superheat that would be maintained for a given pressure of the refrigerant at the evaporator outlet, since, again referring to Figure 5, the line D would be moved upwardly but since the line could not be made to coincide with the line F, the valve would not maintain the superheat constant for varying temperatures and pressures at the evaporator outlet.

In my arrangement, the diaphragm moves in response to variations in pressure of the refrigerant leaving the evaporator outlet, but variations in temperature of the refrigerant at the

evaporator outlet will have substantially no effect upon the position of the diaphragm. Except when the temperature at bulb 39 remains constant, there is no direct relationship between the position of the diaphragm and the valve position by reason of the nature of the connections between the diaphragm and the valve element, and this is an important feature of this invention which contributes to the new result which is obtained thereby. For any position of the diaphragm, the valve position will depend upon the temperature of the refrigerant leaving the evaporator. The position of the diaphragm depends upon the pressure of the refrigerant leaving the evaporator. Furthermore, the position of the diaphragm for any refrigerant pressure depends upon the spring loading and the spring rate which, if properly adjusted, will cause the valve to maintain any desired degree of superheat, and maintain the superheat substantially constant for varying outlet pressures and temperatures.

With this form of valve therefore it will be apparent that it may be set for different degrees of superheat by adjusting the loading and spring rate of the spring 45, and will maintain the superheat constant for varying degrees of pressure and temperature. By placing the diaphragm 42 at the valve outlet the necessity of using the usual equalizer connection is obviated and the only connection between the valve and the evaporator outlet which is required is the tube 38. This arrangement is made possible since the pressure responsive diaphragm 42 does not act downwardly upon the valve but acts merely to adjust the volume of the bulb 39 which in turn varies the expansion of the operating bellows 31. It should be understood that any suitable control means for the refrigerating apparatus may be provided.

Referring to Figure 2, the valve and operating mechanism herein illustrated are formed as a unitary structure as distinguished from the apparatus shown in Figure 1 in which the bulb and pressure responsive diaphragm are formed as a unit separate from the expansion valve itself. In this form of the invention the valve is shown to be made of a plurality of sections 70, 71, 72, and 73. The section 70 includes the inlet opening 74 and the outlet opening 75, the valve element 76 carried by the lever 77 and pivoted at 78 cooperating with the opening 75, the valve being biased towards closed position by means of the spring 79. Clamped between the sections 71 and 72 is a diaphragm 80, the sections 71 and 72 being suitably recessed as illustrated to permit movement of the diaphragm with respect to these sections and to form a pressure chamber above the diaphragm. Connected to the diaphragm 80 is the plunger 81 extending through the opening 82 in the section 71, this plunger acting on the lever 77 so that as the diaphragm 80 moves downwardly the movement thereof is transmitted by the plunger 81 to the lever 77 to move the valve element towards open position. The space within the section 70 is sealed from the diaphragm by means of the bellows 83 connected to the plunger 81. The upper portion of the diaphragm communicates by means of the passageway 84 with the capillary tube 85 connected to a bulb 86 which is subjected to the temperature of the refrigerant in the outlet of the evaporator, this bulb and tube being provided with a suitable fill which may be a volatile or liquid fill so that as the temperature of the refrigerant leaving the evaporator increases, an

increased pressure will be exerted downwardly on the top of the diaphragm 80 which will cause an opening movement of the valve 76.

Clamped between the sections 72 and 73 is a diaphragm 90, the under portion of which has connected thereto a bellows 91 sealed to the section 72, as illustrated. The space between the diaphragm 90 and the section 72 formed by recessing the upper portion of this section is placed in communication with the outlet of the evaporator by means of the port 94 and the tube 95. The tubes 85 and 95 may be concentrically arranged as illustrated so that the bulb 86 may be mounted within the evaporator outlet to more accurately respond to the temperature of the refrigerant leaving the evaporator as disclosed in the above mentioned Newton application. The diaphragms 80 and 90 are suitably connected together by a tension spring 96 so that if the diaphragm 90 is moved upwardly by reason of an increase in pressure at the evaporator outlet the tension of the spring 96 will be increased and will cause the diaphragm 80 to move in the same direction thus permitting movement of the valve 77 towards closed position. The upward movement of the diaphragm 90 is opposed by means of a compression spring 100 with which cooperates adjusting screws 101 and 102 for adjusting the loading and spring rate of the spring as illustrated in Figure 1.

It will be noted that the area of the diaphragm 90 is larger than that of the diaphragm 80 which moves directly in accordance with the temperature of the refrigerant leaving the evaporator and while the bellows 91 reduces the effective area of the diaphragm 90 it reduces by the same amount the effective area of the diaphragm 80 and the areas of the two diaphragms will be so chosen that with the proper adjustments of the spring 100 the superheat of the refrigerant leaving the evaporator will be maintained at the desired value. The diaphragm 90, it should be noted, does not directly control the position of the valve 77 but when used with a volatile fill in the bulb 86, acts merely to adjust the tension of the spring 96 which exerts a closing force on the valve so that when the pressure of the refrigerant increases, the tension of this spring is increased and the diaphragm 80 will move upwardly thus increasing the closing force exerted on the valve by the spring 79. Similarly upon a decrease in pressure the downward movement of the diaphragm will reduce the force exerted by the spring 96 and the diaphragm 80 will move downwardly so that a smaller force must be exerted on the diaphragm 80 to open the valve. However, when a liquid fill is used in the bulb 86 and the chamber above the diaphragm 80, the spring 96 can be omitted without substantially affecting the proper operation of the valve 76 because a liquid will tend to remain at a constant volume without the assistance of a spring.

Referring now to Figure 3, the structure of the valve is quite similar to that of Figure 2 except that bellows replace the operating diaphragms and that an adjustment is provided for the spring 79. The bellows 110 which has its interior connected to the capillary tube 85 leading to the bulb 86 has one end sealed to the partition 111 which divides the valve casing into two chambers which are in communication by way of the opening 112. Refrigerant enters the opening 113 in the upper section of the valve casing and passes through the opening 112 and outwardly from the valve by way of the opening 114 which is controlled by

the valve element 76. The lower end of the bellows 110 is connected to a plate member 116 which moves with the bellows and which receives the compression spring 117 having the adjustable abutment 118 threadedly received within the closure member 120 in the lower wall of the valve casing. The bellows 110 is sealed to the lower wall of the casing by means of the sealing bellows 121. Carried by the periphery of the plate member 116 are pins 122, only one of which is illustrated, which bear against the free arms of the lever 77 which may be in the form of a yoke, and downward movement of the plate member by reason of an increase in pressure within the bellows 110 will cause an upward or opening movement of the valve element 76 against the force of the closing spring 79.

Sealed to the upper wall of the partition 111 is a bellows 125 having its upper end connected to the plate member 126 which is in turn sealed by means of the bellows 127 to the closure member 128. The interior of this bellows is in pressure responsive communication with the outlet of the evaporator by means of the pipe 95 and the passageway 94. The plate members 116 and 126 connected to the bellows 110 and 125, respectively, are connected to a tension spring 135 which tends to maintain the bellows 110 and 125 in a collapsed condition. This spring passes through the opening 136 in the center of the partition 111 and a sealing bellows 137 seals the interior of the bellows 125 from this opening so that the bellows 110 and 125 are properly sealed from one another.

The plate member 126 is biased downwardly by means of the spring 100 having adjusting means 161 and 162 similar to that shown in Figure 2. The bellows 110 and 125 will be kept in a warm condition at all times since they are surrounded by high pressure refrigerant entering the inlet 113 as is apparent from the drawings. The seal-off bellows 121 and 127 prevent the pressure of the high pressure refrigerant from effecting the operation of bellows 110 and 125, respectively.

The operation of this valve is substantially the same as that of Figure 2 since an increase in pressure will cause expansion of the bellows 125 and upward movement of the plate member 126 which will increase the tension in the spring 135 which will tend to allow movement of the valve 104 towards closed position. Upon an increase in temperature of the refrigerant at the evaporator outlet the bellows 110 will expand, moving the plate member 116 downwardly thus causing opening movement of the valve 76. The bellows 110 which responds to the temperature of the refrigerant is made of smaller area than the bellows 115 so that in cooperation with the spring 100 the desired values of superheat of the refrigerant at the evaporator outlet will be maintained constant regardless of normal fluctuations in temperature and pressure.

In both Figures 2 and 3, if the temperature of the refrigerant at the evaporator outlet should become sufficiently low, the diaphragm 80 or bellows 110 will not exert sufficient force to open the valve against the closing force exerted by the spring 79 in Figure 2, or the springs 79 and 117 in Figure 3, regardless of how low the pressure becomes. In other words, these springs 96 and 135 connecting the operating bellows or diaphragms may exert no force whatever because the pressure of the refrigerant has dropped so low, but if the temperature has also dropped so

low that the force of the spring 79 in Figure 2 or the springs 79 and 117 in Figure 3 is not overcome the valves will remain in closed positions. A certain amount of force is of course required to overcome springs 79 and 117 and the evaporator temperature may drop so low that the required force on diaphragm 80 or bellows 110 may not be developed and the valves will remain closed.

This will normally happen only when the load thereon becomes very light. When this happens however the temperature of the refrigerant leaving the evaporator may drop below a certain value whereupon the valves will close entirely and will not open again until this temperature has risen above this value. Before this happens however the pressure within the evaporator will continue to drop so that the superheat at this time at the outlet of the evaporator will increase and the evaporator coil will gradually become more and more starved. The ratio of latent cooling to sensible cooling will thus increase by reason of the diminishing effective coil area and the simultaneous reduction in pressure in the evaporator which is very desirable under light load conditions. The spring 117 in Figure 3 is made adjustable so that the temperature at which the valve is closed regardless of the pressure may be adjusted according to the requirements of the system. It should of course be understood that the spring 79 of Figure 2 may, if desired, also be made adjustable for the same purpose.

It will accordingly be seen that the valves of Figures 2 and 3, besides operating to maintain constant any desired degree of superheat over a normal operating range, also operate to prevent the flow of refrigerant to the evaporator whenever the temperature of the refrigerant at the outlet thereof drops below a predetermined value. This is made possible by reason of the novel arrangement of the operating bellows or diaphragms, the one responding to the pressure of the refrigerant not being directly connected to the valve but merely acting upon a tension spring which acts to vary the opening force thereon exerted by the temperature responsive bellows or diaphragm. This novel arrangement therefore serves two purposes, namely, it permits the adjustment of the superheat setting of the valve so that different constant degrees of superheat may be maintained and it permits automatic closing of the valve whenever the temperature of the refrigerant leaving the evaporator drops sufficiently low regardless of the suction pressure.

Having described some preferred forms of my invention it will be obvious that many modifications will become apparent to those skilled in the art and I therefore wish it to be understood that my invention is limited only by the scope of the appended claims.

I claim as my invention:

1. In a refrigeration system, an evaporator, valve means for controlling the flow of refrigerant through said evaporator, means responsive to a pressure corresponding to the temperature of the refrigerant at the evaporator outlet for adjusting the position of said valve means, means responsive to the pressure of the refrigerant at the outlet of the evaporator for modifying said first responsive means in a manner to maintain the refrigerant leaving the evaporator at a substantially constant degree of superheat as the temperature and pressure of the refrigerant

erant leaving the evaporator vary, and means for modifying the action of one of said last named means in a manner to cause the valve to maintain a different substantially constant degree of superheat of the refrigerant at the evaporator outlet for varying temperatures and pressures of the refrigerant at the outlet.

2. In a refrigeration system, an evaporator, valve means for controlling the flow of refrigerant through said evaporator, means responsive to the temperature of the refrigerant leaving the evaporator controlling the position of said valve means, means responsive to the pressure of the refrigerant on the suction side of the system for modifying the effect of the temperature responsive means, spring means cooperating with the pressure responsive means, means for adjusting the loading and spring rate of said spring means, to cause the refrigerant at the evaporator outlet to be maintained at a substantially constant degree of superheat which varies in accordance with the spring rate and loading on said spring means but which does not vary appreciably with normal changes of temperature or pressure of the refrigerant at the evaporator outlet.

3. In a refrigeration system, an evaporator, valve means for controlling the flow of refrigerant through said evaporator, means responsive to the temperature of the refrigerant leaving the evaporator controlling the position of said valve means, means responsive to the pressure of the refrigerant on the suction side of the system for modifying the effect of the temperature responsive means, spring means cooperating with the pressure responsive means, means for adjusting the loading and spring rate of said spring means, to cause the refrigerant at the evaporator outlet to be maintained at a substantially constant degree of superheat which varies in accordance with the spring rate and loading on said spring means but which does not vary appreciably with normal changes of temperature or pressure of the refrigerant at the evaporator outlet, and means urging the valve in closing direction for preventing opening of the valve means whenever the temperature of the refrigerant at the evaporator outlet drops to a predetermined value irrespective of the pressure of the refrigerant at the evaporator outlet.

4. In a refrigeration system, an evaporator, valve means for controlling the flow of refrigerant through the evaporator, pressure responsive means for controlling the position of said valve means, a fluid filled expansible and contractible bulb responsive to the temperature of the refrigerant leaving the evaporator in communication with said pressure responsive means, said pressure responsive means causing opening movement of said valve means upon a rise in pressure occasioned by a rise in temperature at said bulb, and means responsive to the pressure of the refrigerant at the evaporator outlet for varying the volume of said bulb to vary the effect of the temperature of the refrigerant leaving the evaporator on the position of said valve means.

5. In a refrigeration system, an evaporator, valve means for controlling the flow of refrigerant through the evaporator, pressure responsive means for controlling the position of said valve means, a fluid filled expansible and contractible bulb responsive to the temperature of the refrigerant leaving the evaporator in communication with said pressure responsive means, said pressure responsive means causing opening

movement of said valve means upon a rise in pressure occasioned by a rise in temperature at said bulb, means responsive to the pressure of the refrigerant at the evaporator outlet for varying the volume of said bulb to vary the effect of the temperature of the refrigerant leaving the evaporator on the position of said valve means, and means controlling the change in volume of said bulb for a given change in pressure of the refrigerant at the evaporator outlet in a manner to maintain the superheat of the refrigerant leaving the evaporator at a substantially constant value regardless of normal variations in the pressure or temperature of the refrigerant at the evaporator outlet.

6. In a refrigeration system, an evaporator, valve means for controlling the flow of refrigerant through the evaporator, pressure responsive means for controlling the position of said valve means, a fluid filled expansible and contractible bulb responsive to the temperature of the refrigerant leaving the evaporator in communication with said pressure responsive means, said pressure responsive means causing opening movement of said valve means upon a rise in pressure occasioned by a rise in temperature at said bulb, means responsive to the pressure of the refrigerant at the evaporator outlet for varying the volume of said bulb to vary the effect of the temperature of the refrigerant leaving the evaporator on the position of said valve means, and means controlling the change in volume of said bulb for a given change in pressure of the refrigerant at the evaporator outlet in a manner to maintain the superheat of the refrigerant leaving the evaporator at a substantially constant value regardless of normal variations in the pressure or temperature of the refrigerant at the evaporator outlet, said last named means including a spring and means for individually adjusting both the loading and spring rate of said spring.

7. In a refrigeration system, an evaporator, valve means for controlling the flow of refrigerant through the evaporator, a pressure responsive means acting on said valve means and causing opening movement thereof as the pressure to which the pressure responsive means is subjected increases, a bulb having an expansible fluid fill having its interior in communication with said pressure responsive means, said bulb being located within the outlet of the evaporator whereby it is subjected to the temperature of the refrigerant leaving the evaporator, said bulb being in communication with an expansible bellows, means responsive to the pressure in the outlet of the evaporator sealing said bellows and arranged to cause the expansion of said bellows upon a rise in pressure in the evaporator outlet, and biasing means opposing movement of said last named pressure responsive means.

8. In a refrigeration system, an evaporator, valve means for controlling the flow of refrigerant through the evaporator, operating means for controlling the position of said valve means, said operating means including a first pressure responsive means operatively connected to said valve means, a second pressure responsive means, resilient means connecting said pressure responsive means and biasing the same towards one another, and means subjecting the adjacent portions of the pressure responsive means respectively to a pressure corresponding to the temperature of the refrigerant at the evaporator outlet and to the pressure on the suction side of

the refrigeration system so as to urge said adjacent portions away from each other.

9. In a refrigeration system, an evaporator, valve means for controlling the flow of refrigerant through the evaporator, operating means for controlling the position of said valve means, said operating means including a first pressure responsive means operatively connected to said valve means, a second pressure responsive means, resilient means connecting said pressure responsive means and biasing the same towards one another, means subjecting the adjacent portions of the pressure responsive means respectively to a pressure corresponding to the temperature of the refrigerant at the evaporator outlet and to the pressure on the suction side of the refrigeration system, additional springs means for biasing the second temperature responsive means towards the first pressure responsive means, and means for varying the loading and the spring rate of said springs means.

10. In a refrigeration system, an evaporator, valve means for controlling the flow of refrigerant through the evaporator, operating means for controlling the position of said valve means, said operating means including a pair of adjacent substantially parallel arranged diaphragms, means sealing the adjacent faces of said diaphragms from one another, resilient means connecting said diaphragms and biasing the same towards one another, one of said diaphragms being connected to said valve means, means subjecting the inner face of said one diaphragm to a pressure corresponding to the temperature of the refrigerant at the outlet of the evaporator, and means subjecting the inner face of the other diaphragm to the pressure on the suction side of the refrigeration system.

11. In a refrigeration system, an evaporator, valve means for controlling the flow of refrigerant through the evaporator, operating means for controlling the position of said valve means, said operating means including a bellows having a movable portion operatively connected to said valve, means subjecting the interior of said bellows to a pressure corresponding to the temperature of the refrigerant at the outlet of the evaporator, means urging the movable portion of said bellows in a valve closing direction, said means including a member movable in response to variations in pressure on the suction side of the refrigeration system and means comprising a tension spring connecting said member to the movable portion of said bellows.

12. In a refrigeration system, an evaporator, valve means for controlling the flow of refrigerant through the evaporator, operating means for controlling the position of said valve means, said operating means including a bellows having a movable portion operatively connected to said valve, means subjecting the interior of said bellows to a pressure corresponding to the temperature of the refrigerant at the outlet of the evaporator, means urging the movable portion of said bellows in a valve closing direction, said means including a member movable in response to variations in pressure on the suction side of the refrigeration system and connected to the movable portion of said bellows by a tension spring, the effective area of said bellows being smaller than the effective area of said pressure responsive member, spring means urging said member in a direction to decrease the tension of said spring, means for adjusting the spring rate

of said spring means, and additional means for adjusting the loading of said spring means.

13. In a refrigeration system, an evaporator, valve means for controlling the flow of refrigerant through the evaporator, means forming an expansible chamber having a pair of movable wall portions, tension means urging said wall portions towards one another, means operatively connecting one of said wall portions to the valve means, means subjecting the interior of said chamber to a pressure corresponding to the temperature of the refrigerant at the evaporator outlet, and means urging said other wall portion in a direction to increase the tension of said tension means in response to an increase in pressure on the suction side of the refrigeration system.

14. In a refrigeration system, an evaporator, valve means for controlling the flow of refrigerant through the evaporator, means forming an expansible chamber having a pair of movable wall portions, tension means urging said wall portions towards one another, means operatively connecting one of said wall portions to the valve means, means subjecting the interior of said chamber to a pressure corresponding to the temperature of the refrigerant at the evaporator outlet, means urging said other wall portion in a direction to increase the tension of said tension means in response to an increase in pressure on the suction side of the refrigeration system, and adjustable spring means urging said second wall portion in a direction to decrease the tension of said tension means.

15. In a refrigeration system, an evaporator, valve means for controlling the flow of refrigerant through the evaporator, an operating member for said valve means, means responsive to the pressure of the refrigerant on the suction side of the refrigeration system, hydraulic force transmitting means for transmitting movements of said pressure responsive means to said valve means, said hydraulic force transmitting means including an expansible fluid, a portion of said expansible fluid being subjected to the temperature of the refrigerant leaving the evaporator whereby said valve means also moves in response to variations in temperature of the refrigerant at the evaporator outlet.

16. In a refrigerating system, an evaporator, valve means for controlling the flow of refrigerant through said evaporator, means responsive to the pressure and temperature of the refrigerant leaving the evaporator for controlling the valve to maintain the refrigerant leaving the evaporator at a substantially constant degree of superheat, said last means embodying means for compensating for variations in evaporator pressure so that the degree of superheat remains constant even though the evaporator pressure varies, means for adjusting the second mentioned means for varying the degree of superheat to be maintained by adjusting the responsiveness of said responsive means, said adjusting means embodying secondary adjusting means cooperating with said compensating means whereby variations in evaporator pressure are compensated for at the adjusted value of superheat so that degree of superheat may be maintained constant at selected values irrespective of evaporator pressure.

17. In a refrigerating system, an evaporator, valve means for controlling the flow of refrigerant through said evaporator, means responsive to the pressure and temperature of the refrigerant leaving the evaporator for controlling the

valve to maintain the refrigerant leaving the evaporator at a substantially constant degree of superheat, said last means embodying means for compensating for variations in evaporator pressure so that the degree of superheat remains constant even though the evaporator pressure varies, means for adjusting second mentioned means for varying the degree of superheat to be maintained by adjusting the responsiveness of said responsive means, said adjusting means embodying secondary adjusting means, cooperating with said compensating means whereby variations in evaporator pressure are compensated for at the adjusted value of superheat so that degree of superheat may be maintained constant at selected values irrespective of evaporator pressure, said secondary adjusting means comprising an adjustable spring having means for adjusting its spring rate.

18. In apparatus of the character described, in combination, refrigerant circulating means including an evaporator, valve means controlling the supply of refrigerant to the evaporator, said

5 valve means including a pressure chamber having a movable wall portion, means communicating evaporator pressure to said chamber urging said wall portion in one direction, means forming a second pressure chamber having a movable wall portion, means producing a pressure in said last chamber corresponding to the temperature of refrigerant at the outlet of the evaporator, resilient means opposing movement of one of said wall portions, yieldable means interposed between said movable wall portions and a valve member connected to one of said wall portions adapted to assume a position depending on both wall portions, and said resilient means comprising a 15 spring having manual means for adjusting both its loading and spring rate, the valve means being arranged to maintain a constant number of degrees of superheat at the outlet of the evaporator even though the evaporator pressure varies, the number of degrees of superheat depending on the adjustments of said manual means.

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