June 13, 1950 F. Y. CARTER 2,511,565

REFRIGERATION EXPANSION VALVE

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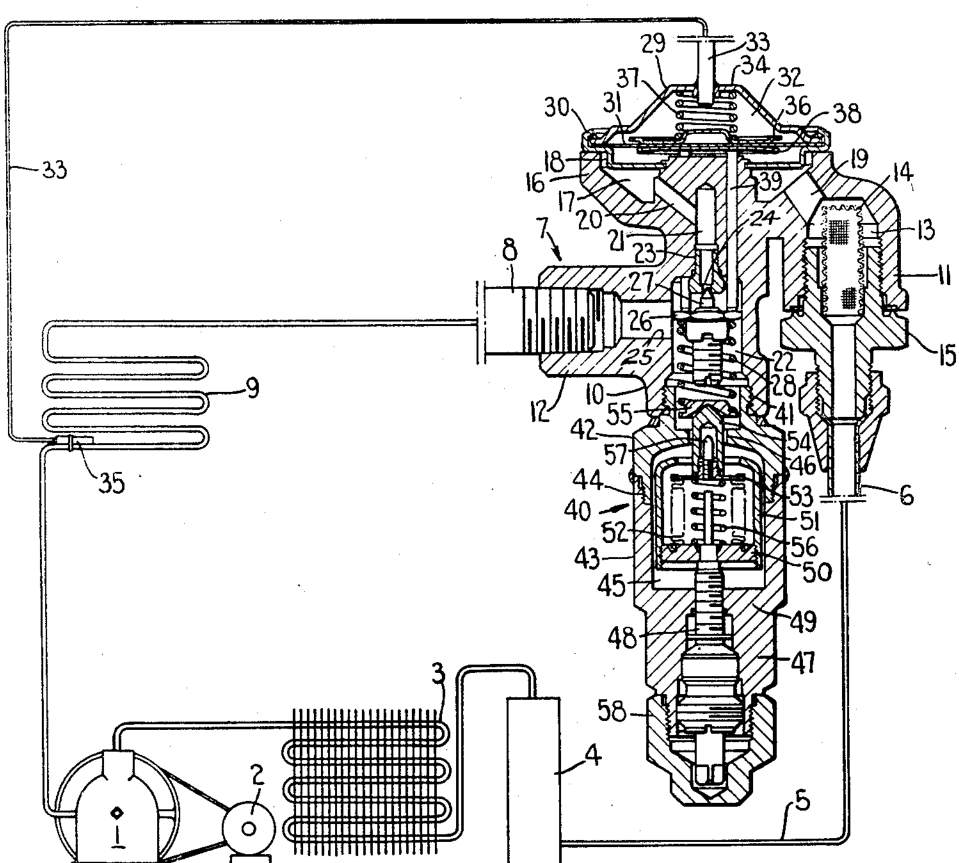

FIG. 1

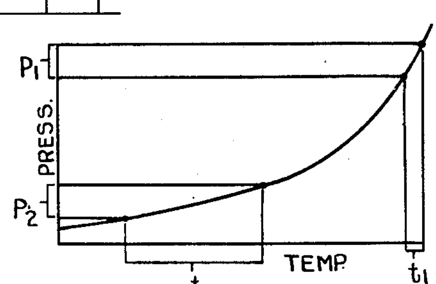

FIG. 2

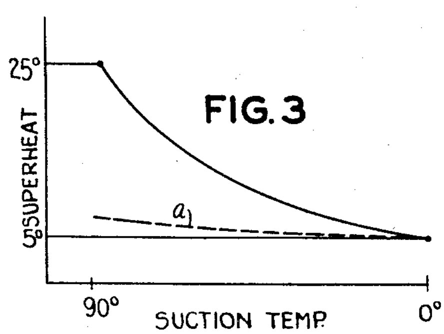

FIG. 3

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REFRIGERATION EXPANSION VALVE

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4 Claims. (Cl. 62—8)

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This invention relates to new and useful improvements in refrigeration expansion valves.

One of the objects of this invention is to provide a refrigeration expansion valve having a means to vary superheat setting of the valve in accordance with the variation of a characteristic of the refrigerant fluid passing through the valve.

Another object is to provide a refrigeration expansion valve having a means to vary the superheat setting of the valve in accordance with the temperature at which the valve is operated.

Another object is to provide a means for reducing the amount of increase of superheat setting in thermostatic expansion valves at low operating temperatures.

Other objects will be apparent from time to time throughout the specification and claims as hereinafter related.

This invention comprises the new and improved construction and combination of parts and the cooperative relation therebetween which will be described more fully hereinafter and the novelty of which will be particularly pointed out and distinctly claimed.

In the accompanying drawings, to be taken as part of the specification there is clearly and fully illustrated one preferred embodiment of this invention in which drawing:

Figure 1 is a view in longitudinal cross section of a refrigeration expansion valve embodying one form of this invention, which valve is shown diagrammatically in a refrigeration system,

Fig. 2 is an illustrative pressure-temperature curve to show the variation of required temperature differentials for opening an expansion valve upon change of operating temperature, and

Fig. 3 is a curve showing change of superheat setting of a conventional expansion valve upon decrease of operating temperature.

Referring to the drawing by characters of reference, there is a compressor 1 driven by a motor 2 which supplies refrigerant to a condenser 3 and a receiver 4. From the liquid refrigerant receiver 4 refrigerant passes through a conduit 5 to the inlet 6 of a thermostatic expansion valve 7 which embodies this invention. The outlet 8 of the expansion valve 7 is connected to an evaporator 9 which is in turn connected to the suction side of the compressor 1. The expansion valve 7 comprises a main body portion 10 having an inlet projecting portion 11 and an outlet projecting portion 12. There is a cavity 13 in the inlet projecting portion 11 which houses a strainer 14 which is held in position by an inlet fitting 15 into which opens the inlet 6. The valve casing

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10 has an enlarged end portion 16 with an annular cavity 17 therein. There is an end wall member 18 which covers the enlarged end portion 16 and closes the annular cavity 17. The inlet cavity 13 is connected by a passageway 19 to the annular cavity 17 which is in turn connected by passageways 20 and 21 to a longitudinal cavity 22 in the valve casing 10. There is a hollow plug member 23 screw-threadedly secured in the passageway 21 and forming a valve port 24 for discharge of refrigerant into the cavity 22. There is an outlet passageway 25 leading from the cavity 22 through the outlet projecting portion 12. Positioned in the valve cavity 22 there is a valve carrier member 26 which is operable to have longitudinal movement therein and which carries a valve member 27 which is cooperable with the plug or valve seat member 23. There is a helical spring 28 which is compressively positioned against the valve carrier member 26 and is operable to urge the valve member 27 toward closed position. At the enlarged end 16 of the valve casing 10 there is a dish-shaped cover member 29 which covers the end cover member 18 and which is secured thereto by an inturned flange portion 30 of the end member 18. Positioned between the end member 18 and the cover member 29 is a flexible diaphragm 31 which is sealed between the circumferential edges of the end member 18 and the cover member 29 and which forms with the cover member 29 an enclosed chamber 32. There is a conduit 33 which is secured in an aperture in the end wall portion 34 of the cover member 29 and which opens into the chamber 32. The other end of the conduit 33 has secured thereon a thermostatic bulb element 35 which contains a volatile thermostatic fluid responsive to temperature changes and operable to transmit pressure to the enclosed chamber 32 to actuate the diaphragm 31. Within the chamber 32 there is a plate member 36 positioned on the diaphragm 31. Also within the chamber 32 there is a helical spring 37 compressively positioned between the cover member end wall portion 34 and the plate member 36. On the other side of the diaphragm 31 there is another plate member 38 which is operable to transmit movement of the diaphragm 31 to a plurality of thrust rods 39 which are slidably positioned in longitudinal passageways in the valve casing 10. The thrust rods 39 are operable to transmit movement from the diaphragm 31 to the valve carrier member 26 and operate to move the valve member 27 in opposition to the compressive force of the spring 28. There is a projecting casing portion 40 which is

screw-threadedly secured to the valve casing 10 as at 41 and which is formed in two sections 42, 43 which are screw-threadedly secured together as at 44. There is a hollow cavity 45 in the casing portion 40 which is connected by an aperture 46 to the cavity 22 in the main casing 10. The casing portion 40 has a hollow end portion 47 in which is positioned an adjustment screw 48 which extends through an aperture in the end wall 49 of the casing portion 40. Secured on the end of the adjustment screw 48 is the base portion 50 of a cylindrical member 51 in which is positioned an expansible-contractable bellows 52. The bellows 52 is sealed to the base portion 50 and has a closed end wall member 53 from which extends the projecting cylindrical abutment 54 which extends through the aperture 46 and engages the base of a supporting member 55 for the helical spring 28. Positioned within the bellows 52 is a helical spring 56 which urges the bellows toward an expanded position. The bellows 52 is charged through a filler tube 57 with volatile thermostatic fluid which has a different rate of change of pressure with temperature than the refrigerant fluid used in the system. The superheat setting of this valve is determined by adjustment of the screw 48 which varies the compression of the spring 28 acting on the valve carrier member 26. There is a cover member 58 which closes the adjustment screw end portion of the projecting portion 47.

In operation this form of the invention functions as follows:

This expansion valve, at normal operating temperatures, functions as a conventional expansion valve, the operation of which is obvious from the system illustrated. Refrigerant vapor is compressed by the compressor 1, condensed in the condenser 3 and supplied to the receiver 4 from which liquid refrigerant passes through the conduit 5 to the inlet 6 of the expansion valve. From the outlet 8 of the expansion valve 7 refrigerant passes to the evaporator 9 wherein the refrigerant fluid is evaporated for cooling and from which evaporator the refrigerant vapor passes to the suction side of the compressor 1. The expansion valve 7 is designed to respond normally to the pressure at the inlet and to the temperature at the outlet end portion of the evaporator 9. Changes in temperature at the outlet of the evaporator 9 and the bulb 35 result in a change of pressure within the chamber 32 thereby changing the differential of pressure across the diaphragm 31 to cause movement thereof thereby to move the pins or thrust rods 39 to move the valve member 27 toward or away from its seat to permit greater or less flow of refrigerant through the valve. The differential of pressure across the diaphragm 31, necessary to move the valve member 27 is determined by the extent of compression of the spring 28 acting in opposition thereto. The spring 28 as heretofore mentioned is operable to determine the superheat setting of the valve.

Referring to Fig. 2 there is shown a pressure-temperature curve for a volatile liquid refrigerant. For operation of the expansion valve in the usual temperature range of say 30 to 40° F. a certain pressure differential will be required to begin opening of the valve. On the pressure temperature curve this opening pressure differential (commonly known as superheat when expressed as a temperature differential) is shown as p_1; projecting the pressure differential p_1 on the pressure-temperature curve and then projecting the temperature differential to the temperature axis we find that a temperature differential t_1 is required to begin to open the valve. When the valve is operated at a very low temperature such as minus 60° F. or lower the pressure differential required to open the valve will be substantially the same as that which is indicated on the curve as p_2. While the pressure requirement p_1 and p_2 are substantially equal the pressure-temperature curve at this extremely low temperature is of a much lower slope than at plus 30° to 40° F.; hence, the temperature differential required to produce this pressure differential for opening the valve will be much greater, as for example, t_2. It is seen then from this reference to the pressure temperature curve that the opening temperature differential of the valve is affected by operation at extremely low temperatures.

Referring to the superheat curve in Fig. 3 we find that if a valve of the single diaphragm type is operated at say 0° with a 5° superheat setting and this same valve is then operated at say minus 90° the superheat setting of the valve will be found to have increased to about 25°. This increase of superheat setting is characteristic of single diaphragm type valves when operated at extremely low temperatures and the cause is apparent from the previous reference to the pressure temperature curve of Fig. 2. The change of superheat setting is especially pronounced when the bulb element is charged with the same fluid as that used in the system. In the expansion valve shown in Fig. 1 there has been provided a means to compensate for this tendency for excessive increase in superheat upon operation of the valve at extremely low temperatures. The spring 28 which determines the superheat setting of the valve is held in its compressed position by the bellows 52 and thrust member portion 54. The bellows 52 is normally charged with a volatile fluid having a greater rate of change of pressure with temperature than the refrigerant used in the system so that upon decrease of operating temperature of the valve the pressure within the bellows 52 will decrease at a slightly greater rate than the pressure outside the bellows. The bellows 52 by reason of being only partly filled with volatile liquid is responsive to temperature and pressure of fluid refrigerant on the outlet side of the valve port 24 which enters the chamber or cavity 45 through the aperture 46. This described decrease of pressure within the bellows 52 will cause the bellows to collapse a predetermined amount in accordance with the temperature and pressure of the refrigerant outside the bellows relative to the pressure inside the bellows thereby decreasing the compressive force of the spring 28 and permitting the valve member 27 to be moved by lower pressure differentials across the diaphragm 31. This decrease in pressure differential required to open the valve member 27 will cause a decrease in the superheat setting of the valve for the temperature at which it is operated so that the increase of superheat setting at extremely low temperatures will be greatly reduced and will follow a compensated curve such as the dotted superheat curve "*a*" in Fig. 3.

The following example is given to illustrate fully the operating characteristics of this valve. It should be understood, however, that other refrigerants could be used subject to proper selection of the relative sizes of the springs and bellows. Assume that the system, the bulb element 35, and the space 32 are charged with

"F-12" (CCl_2F_2), and that the compensating bellows 52 is charged with "F-22" ($CHClF_2$). Assume an operating area of one square inch for the diaphragm 31, an operating area of .31 square inch for the bellows 52 (a standard ¾" bellows), a force of 5 pounds for the spring 37, and a superheat setting of 10° at 0° F. At 0° F. bulb temperature the pressure of the refrigerant "F-12" in the chamber 32 acting on the diaphragm 31 is 23.9 p. s. i. (or 23.9 pounds for a one square inch diaphragm). The total pressure acting downward on the diaphragm 31 then is 23.9 pounds plus the 5 pounds force of the spring 37 or a total of 28.9 pounds. At a 10° superheat setting the suction temperature in the valve is minus 10° F. and the pressure of "F-12" acting upward against the diaphragm 31 is 19.2 pounds. The difference between the downward and upward forces on the diaphragm 31 is 9.7 pounds net downward force which force is equalized by the spring 28 which is calibrated to resist this force. Assume, for a moment, that this expansion valve has no compensating bellows and the rise in superheat at very low temperatures will be demonstrated. When the valve is operated at a suction temperature of minus 80° F. the pressure of the "F-12" upward on the diaphragm 31 is only 2.9 pounds which plus the 4.7 pounds net force of the spring 28 over the spring 37 gives a total upward force of 7.6 pounds which is counteracted by bulb element pressure above the diaphragm 31. This 7.6 pounds (or p. s. i.) above the diaphragm 31 represents a bulb temperature of minus 47° F. and a superheat 33°. It is thus seen that an initial superheat setting of 10° at minus 10° F. suction temperatures will increase to 33° at minus 80° F. The compensating effect of the bellows 52 will now be demonstrated. The bellows 52 and its internal spring 56 must carry the reactive thrust of the spring 28. At the initial suction temperature of minus 10° F. the bellows 52 is fully extended against the inturned end of the cup-shaped member 51. The bellows at this point is carrying the 9.7 pound reactive thrust of the spring 28. The pressure of "F-22" within the bellows 52 (at minus 10° F.) is 31.3 p. s. i. and the pressure of "F-12" around the bellows is 19.2 p. s. i. The net expansive force of the bellows then is 12.1 p. s. i. times .31 square inch or a total force of 3.7 pounds. The force of the spring 56 then must be 6 pounds (i. e., the difference between the 9.7 pound thrust of the spring 28 and the 3.7 pound expansive force of the bellows 52). When the valve is operated at a suction temperature of minus 80° F. the pressure of "F-22" within the bellows 52 is 4.8 p. s. i. and the pressure around the bellows is 2.9 p. s. i. (pressure of "F-12"). This pressure differential is 1.9 p. s. i. or .6 pound (1.9 times .31). The total expansive force of the bellows 52 and spring 56 has thus been reduced to 6.6 pounds (6 pounds spring force plus .6 pounds expansive force) which represents the force now exerted on the diaphragm 31 by the spring 28. The net upward spring force on the diaphragm 31 of 1.6 pounds (i. e., the force of spring 28 of 6.6 pounds minus the 5.0 pound downward force of spring 37) plus the 2.9 pound pressure of "F-12" (at minus 80° F.) on the diaphragm 31 totals 4.5 pounds upward diaphragm force which is counteracted by bulb element pressure above the diaphragm. This 4.5 pound bulb element pressure represents a bulb temperature of minus 65° F. and a superheat setting of 15°. From the foregoing it is seen that the compensating bellows element has materially reduced the increase in superheat setting at very low temperatures. It should be noted that the aforementioned compensation was accomplished by using a standard bellows and by using a slightly larger bellows and a weaker bellows spring the increase could be completely eliminated. It should also be noted that by the use of vapor pressures of different refrigerants (inside and outside the bellows) for compensation the compensation of the superheat curve is logarithmic in nature so that the superheat curve will approach a straight line. Similar compensation can be obtained by use of other refrigerants having high rates of pressure change, such as ammonia, carbon dioxide or ethane and the superheat can actually be reduced below its initial setting if the bulb element and diaphragm chamber are charged with a refrigerant having a very low rate of pressure change (such as methyl chloride).

In summary, it is seen that there is provided a conventional single diaphragm type expansion valve which has the characteristic increase of superheat setting at extremely low operating temperatures. There is also provided a bellows which is charged with a fluid having a rate of pressure change greater that that of the refrigerant used in the system so that upon decrease of operating temperature the bellows will tend to collapse. The collapsing of the bellows as described heretofore is operable to decrease the compression of the spring which tends to close the valve and thus the superheat setting of the valve is reduced so that a much smaller increase of superheat at extremely low temperature is accomplished.

It should be obvious that if for any reason it is desired to increase the superheat setting of the valve at lower temperatures, it would merely be necessary to charge the bellows 52 with a volatile fluid which had a lower rate of change of pressure with temperature than the refrigerant used in the system so that upon decrease of operating temperature the bellows would tend to expand rather than to collapse and thus increase the compression of the spring 28 and with it the superheat setting of the valve. It should also be obvious that by proper selection of a volatile fluid for charging the bellows 52 the superheat curve as shown in Fig. 3 may be compensated in either direction to almost any extent for any desired operating temperature.

Having thus described the invention what is claimed and is desired to be secured by Letters Patent of the United States is:

1. In a refrigeration expansion valve, a movable valve member for controlling flow of refrigerant, thermostatic means cooperable with and operable to move said valve member toward an open position, spring means urging said valve member toward closed position in opposition to said thermostatic means and determining the superheat setting of said valve, an expansible and contractable bellows positioned on the outlet side of the valve and charged with a volatile fluid having a different rate of change of pressure relative to change in temperature than the refrigerant passing through said valve, said bellows being cooperable with said spring means and being responsive to the temperature and pressure of refrigerant flowing from the valve, and said bellows expanding and contracting in accordance with the differential of internal and external pressure therearound to vary the com-

pressive force of said spring means and thereby to vary the superheat setting of said valve.

2. A refrigeration expansion valve comprising a valve casing having an inlet passageway and an outlet passageway, an internal passageway interconnecting said inlet and outlet passageways and having a valve port forming a valve seat, a valve member cooperable with said valve seat to control flow of refrigerant fluid through said port, said outlet passageway being operable to discharge refrigerant fluid to an evaporator, a flexible diaphragm covering one end of said casing, a dish-shaped cover member secured to said casing end and sealing said diaphragm to said casing end, said cover member and said diaphragm forming an expansible and contractable chamber, a thrust rod slidably positioned in said casing and extending from said diaphragm to said valve member, a tube opening at one end into said chamber through said cover member and extending from said cover member, a bulb element secured to the other end of said tube and opening into said tube, said bulb element being charged with a volatile fluid and operable to respond to the temperature of a refrigerant evaporator by transfer of fluid pressure through said tube to said chamber for actuating said diaphragm, said diaphragm being operable in response to the differential between fluid pressure from said bulb element and refrigerant pressure in said valve to move said thrust rod thereby to move said valve member away from said valve seat, a helical spring compressively positioned against said valve member to urge the same toward said valve seat and determining the superheat setting of said valve, a supporting member for said spring, an expansible and contractable bellows positioned on the outlet side of the valve and charged with a volatile fluid having a greater rate of change of pressure relative to change in temperature than the refrigerant fluid passing through said valve, said bellows having an abutment abutting said spring supporting member and being operable upon movement to determine the compression of said spring, said bellows being responsive to the temperature and pressure of refrigerant fluid flowing from said valve port, and said bellows contracting in accordance with the differential of internal and external pressures therearound to reduce the compressive force of said spring at low refrigerant fluid temperature to reduce the superheat setting of said valve thereby to compensate for the increase in superheat setting of said valve at low temperatures.

3. In a refrigeration expansion valve, a movable valve member for controlling flow of refrigerant, thermostatic means cooperable with and operable to move said valve member toward an open position, a spring having one end engaging said valve member and urging the same toward closed position, the compressive force of said spring determining the superheat setting of said valve, a sealed thermostatic element including an expansible and contractible member operatively engageable with and supporting the other end of said spring, said thermostatic element containing a partial charge of volatile liquid having a different rate of change of pressure relative to change in temperature from that of the refrigerant passing through said valve, and said expansible and contractible member being positioned for subjection to the temperature and pressure of the refrigerant on the outlet side of said valve member such that the differential of internal and external fluid pressures acting on said expansible and contractible member determines the compressive force of said spring.

4. In a thermostatic refrigeration expansion valve, a valve casing having a port, a movable valve member cooperable with said port to control flow of refrigerant, thermostatic means operable upon temperature increase to urge said valve member toward open position, means to compensate for change in the valve superheat setting and comprising a sealed thermostatic element including a resilient wall member, said element being partially filled with a volatile liquid having a greater rate of change of pressure relative to change in temperature than the refrigerant to be controlled, said casing having an open chamber on the outlet side of said valve member, said wall member being positioned in said chamber for response to the temperature and pressure of the refrigerant on the outlet side of said valve member, and a spring interposed between said wall member and said valve and urging said valve member toward closed position, the force exerted by said spring being determined by the differential of the fluid pressures acting on the opposite sides of said wall member.

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