Sept. 14, 1948. C. E. WINCHESTER ET AL 2,449,437

SUPERHEAT CONTROL FOR REFRIGERATING APPARATUS

Filed May 27, 1947

Fig. 1.

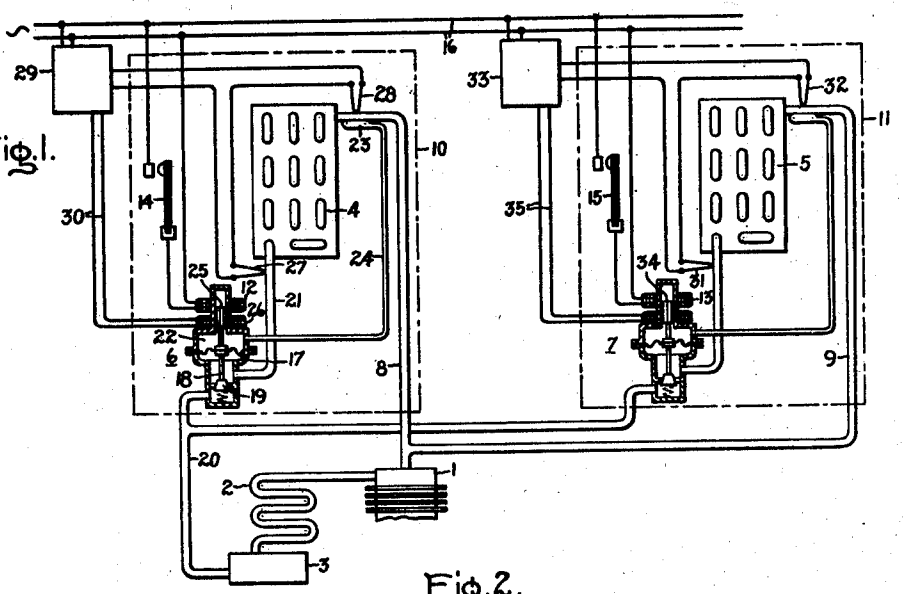


Fig. 2.

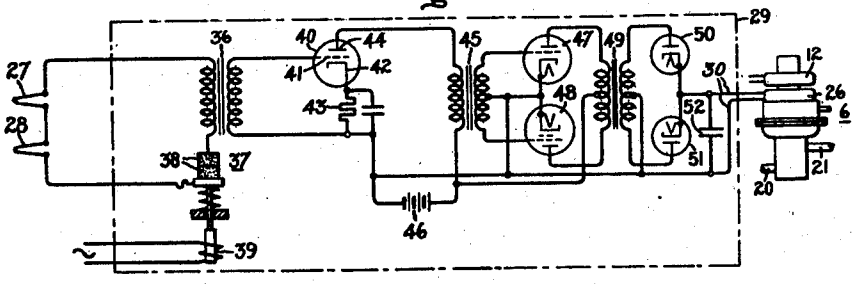
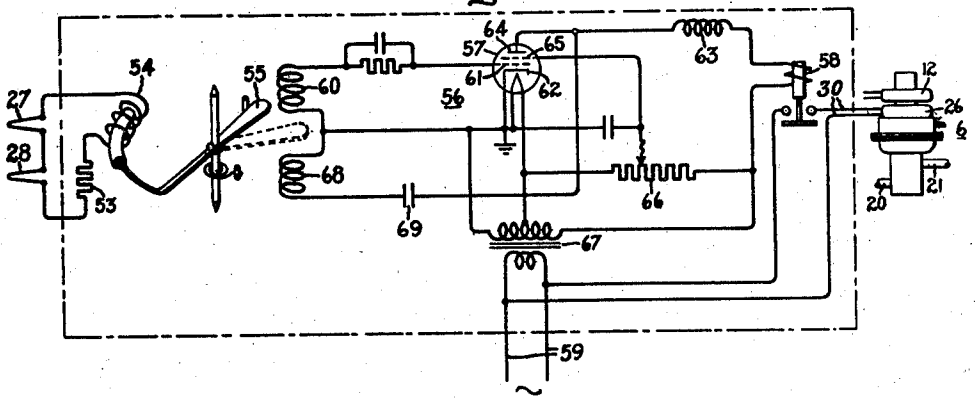


Fig. 3.



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SUPERHEAT CONTROL FOR REFRIGERATING APPARATUS

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6 Claims. (Cl. 62—8)

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This invention relates to refrigerating apparatus and particularly to a flow regulating device for controlling the supply of liquid refrigerant to such apparatus in accordance with the superheat of the vaporized refrigerant withdrawn from the evaporator.

In certain applications of refrigerating machines of the compression type, it is necessary to provide a high degree of sensitivity in the refrigerant flow controlling device which admits liquid refrigerant to the evaporator. It is a common practice to employ thermostatic expansion valves for this purpose. These valves include a control element responsive to the pressure of the refrigerant in the evaporator and a second control element responsive to the temperature of the vaporized refrigerant withdrawn from the evaporator. These two elements are connected in bucking relation and effect control of the refrigerant to maintain a substantially constant amount of superheat in the vaporized refrigerant. In systems requiring high control sensitivity, for example in systems operating at very low temperature, such as those employed in testing internal combustion engines for high altitude operation, the conventional thermostatic expansion valve may be found unsatisfactory. Accordingly, it is an object of this invention to provide a superheat control for refrigerating machines which affords a high degree of sensitivity to changes in pressure and temperature within the evaporator.

It is another object of this invention to provide improved thermostatic expansion valves for refrigerating machines including a device for boosting the actuating force of the valve to secure increased sensitivity over a wide range of operating conditions.

Further objects and advantages of the invention will become apparent as the following description proceeds, and the features of novelty which characterize the invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

For a better understanding of this invention, reference may be had to the accompanying drawing in which Fig. 1 represents diagrammatically a refrigerating system embodying the invention; Fig. 2 is a schematic circuit diagram of an electronic amplifier for one embodiment of the invention; and Fig. 3 is a circuit diagram of an electronic amplifier for a second embodiment of the invention.

Briefly, the refrigerating system illustrated in the drawing comprises a refrigerant liquefying

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unit including a compressor and a condenser and a plurality of refrigerant evaporators connected to receive liquid refrigerant from the condenser and to deliver vaporized refrigerant to the compressor. Each evaporator is provided with a thermostatic expansion valve including the usual evaporator pressure and suction gas temperature controls. In addition to the normal control, the valve is provided with a booster control actuated in accordance with the temperatures of the inlet and outlet of the evaporator as determined by a pair of thermocouples which produce a voltage proportional to the amount of superheat in the vaporized refrigerant. The voltage produced by the thermocouples is amplified electronically and is supplied to a solenoid for boosting the action of the thermostatic expansion valve. In one embodiment, a modulating action is secured, the boosting force being proportional throughout the range of operation to the amount of superheat in the vaporized refrigerant, and in a second embodiment an "on-off" operation is employed, the thermostatic expansion valve being closed whenever the superheat exceeds a predetermined value.

Referring now to the drawing, the refrigerating system illustrated in Fig. 1 comprises a compressor 1 driven by a suitable motor (not shown) and arranged to supply compressed refrigerant gas to a condenser 2. The hot gas is cooled by the circulation of a suitable cooling fluid over the condenser and the resulting liquefied refrigerant enters a receiver 3 from which it is supplied to two evaporators 4 and 5 under control of thermostatic expansion valves 6 and 7 respectively. The liquid refrigerant is vaporized by the absorption of heat and the vaporized refrigerant is returned to the compressor 1 from the evaporators 4 and 5 through suction lines 8 and 9 respectively. The evaporator 4 is arranged to cool a compartment indicated by a dotted line 10, and the evaporator 5 a compartment 11. The valves 6 and 7 are provided with solenoids 12 and 13 respectively connected through thermostats 14 and 15 to a suitable current supply 16. Each of the thermostats 14 and 15 is set to energize its solenoid when the temperature in the corresponding compartment is below a predetermined minimum value. The valve 6 is provided with an expansible diaphragm 17 connected by a rod 18 to a valve member 19. Liquid flows from the receiver 3 through a liquid line 20 and, when the valve 19 is in its open position, is admitted to the evaporator through a second portion 21 of the liquid line. A lower side of the diaphragm 17 is thus subjected to the pressure in the evaporator. The

upper side of the diaphragm 17 is enclosed in a pressure-tight chamber 22 connected to a temperature feeler bulb 23 by the usual pressure transmitting tube 24. The diaphragm 17 thus moves to open the valve 19 on an increase in pressure in the chamber 22 and on a decrease in evaporator pressure below the diaphragm, an increase in evaporator pressure tending to close the valve. The operation in accordance with the resultant difference in pressure controls the flow of refrigerant to the evaporator so that the superheat in the vaporized refrigerant withdrawn from the evaporator is maintained at a predetermined value, this being the value represented by the difference between inlet and outlet temperatures of the refrigerant. When the solenoid 12 is energized by closing of the thermostat 14 a plunger 25 secured to the upper end of the rod 18 is drawn upwardly to close the valve. The thermostatic expansion valve 7 for controlling the flow of refrigerant to the evaporator 5 is of the same construction as the valve 6.

During the normal operation of the expansion valves at very low temperatures, the power for driving the valve is relatively small because the change in pressure is relatively small for a change in temperature as compared with the operation of the valve at higher temperatures. For this reason, accurate control of superheat becomes difficult. In order to overcome the inherent sluggish operation of the valve 6 at low temperatures, a second solenoid indicated at 26 is arranged below the solenoid 12 and in a position to produce a magnetic field for moving the plunger 25. The second solenoid is actuated in accordance with the superheat of the refrigerant as determined by a pair of thermocouples 27 and 28 secured adjacent the inlet and outlet of the evaporator and connected in a series circuit to an electronic amplifying device 29 which energizes the solenoid through leads 30. The thermocouples 27 and 28 are connected in bucking relation so that the combined voltage generated is proportional to the difference in temperatures at the two points and consequently is proportional to the superheat of the vaporized refrigerant. The response of the thermocouple circuit to changes in temperature is substantially instantaneous, and by utilizing the amplifying device 29 it is possible to exert a substantial force on the valve 19 in the same direction as the force of the normal superheat control but with a speed of response substantially greater than that of the normal control. As a result, when the system is operating at low temperatures the superheat is controlled effectively even though the conventional control would otherwise be sluggish. The thermostatic expansion valve 7 is provided with a similar control including thermocouples 31 and 32 at the inlet and outlet respectively and an amplifier 33 connected to a solenoid 34 by leads 35. Because of the high speed of response, the superheat of the refrigerant vapor withdrawn from both the evaporators 4 and 5 may be accurately controlled over a wide range of pressures and temperatures. For example, the system may be operated with satisfactory control of superheat throughout the period of pull-down when the compressor is started with the system at room temperature.

The electronic amplifiers 29 and 33 are so connected that their outputs provide energization of the solenoids 26 and 34 in proportion to the voltage differences measured by the respective pairs of thermocouples. The amplifiers thus provide continuous energization of the solenoids in accordance with the superheat of the suction gas and modulated operation of the valves 6 and 7 is secured. In some systems it may be desirable merely to provide "on-off" operation and for these installations the amplifiers 29 and 33 may be arranged to energize the solenoids and to retain the valve in its open position regardless of the condition of operation of the other actuating elements whenever the temperature difference between the inlet and outlet thermocouples exceeds a predetermined value. Types of these two forms of amplifiers are illustrated by way of example in Figs. 2 and 3.

Referring now to Fig. 2, the amplifier 29 as illustrated therein comprises a transformer 36 having its primary winding connected in series with the thermocouples 27 and 28 and with a variable resistance device 37. The variable resistance device as illustrated comprises a pair of carbon blocks 38 arranged in contact. The pressure between the blocks 38 is varied continuously by pressure exerted by a solenoid 39 excited by alternating current, say at 60 cycles. The resistance of the device 37 is thus varied continuously in accordance with the alternating current wave and any current produced by the thermocouples 27 and 28 is thus varied and may be impressed on an electron discharge device 40 by connecting the secondary of the transformer between a control electrode 41 and a cathode 42 in series with a resistor 43. The device 40 includes an anode 44 connected in an output circuit including the primary winding of a transformer 45 and a suitable source of direct current, such as a battery 46. The secondary of the transformer 45 is connected to supply a pair of electron discharge devices 47 and 48 connected in push-pull relationship and having their outputs connected to the primary of the transformer 49, the secondary winding of which is connected in a circuit including two electron discharge devices 50 and 51 for rectifying the output of the transformer 49 and for supplying rectified current across a capacitor 52 to the solenoid 26 through the leads 30. This amplifier is effective to utilize the very weak output voltage of the pair of thermocouples 27 and 28 to supply a current proportional to the voltage and sufficient for actuating the solenoid 26 and supply a booster action for assuring a quick response of the actuating elements of the thermostatic expansion valve in accordance with changes of conditions in the evaporator.

The "on-off" type of electronic amplifier is illustrated in Fig. 3 and is connected in the same position as the amplifier 29, corresponding parts of the system being indicated by the same numerals. As shown in Fig. 3, the pair of thermocouples 27 and 28 are connected in a series circuit including a resistance 53 and a galvanometer or millivoltmeter coil 54. Energization of the coil 54 varies the position of a vane 55 and, on a predetermined maximum difference in voltage representing a maximum difference in temperature between the thermocouples, the vane 55 moves into the magnetic field between coils 60 and 68 resulting in the stopping of oscillation and sufficient increase in anode current to close a relay 58 and thus connect the leads 30 of the solenoid 26 to a source of alternating current 59. This position of the vane 55 is indicated by the dotted lines. The oscillator 56 includes a coil 60 connected between a control grid 61 and cathode 62 of an electron discharge device 57 and an output inductance 63 connected between an anode 64 of the device 57 and the cathode 62, the coil of

the relay 58 being included in the anode circuit. The electron discharge device 57 also includes a screen grid 65 the potential of which may be adjusted by adjusting a potentiometer 66 connected across a portion of the secondary winding of a transformer 67. The transformer 67 is connected in the load circuit between the cathode 62 and the relay 58 and is continuously energized by alternating current from the line 59 which is connected to the primary of the transformer. A feedback circuit for effecting oscillation comprises a coil 68 connected between the cathode 62 which is at ground potential, and the anode 64 through a capacitor 69. The vane 55 is arranged to move between the coils 60 and 68 and change the coupling therebetween, the oscillator being tuned to go out of oscillation whenever the vane 55 is in a position representing a predetermined maximum difference in temperature between the thermocouples 27 and 28. During oscillation, current in the load circuit is at a minimum and the relay 58 is adjusted to open and deenergize the solenoid 26 and leave the valve 6 under its conventional control.

It will readily be understood that various forms of electronic amplifiers may be employed to secure the desired results, specific circuits having been illustrated merely by way of example and not by way of limitation.

While this invention has been illustrated in connection with a refrigerating machine having a plurality of evaporators, other applications will readily be apparent to those skilled in the art. It is not, therefore, desired that the invention be limited to the particular constructions illustrated and described, and it is intended by the appended claims to cover all modifications within the spirit and scope of the invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. In a refrigerating apparatus including an evaporator and means for supplying liquid refrigerant thereto and for withdrawing vaporized refrigerant therefrom, a thermostatic expansion valve including actuating means dependent upon the superheat of the vaporized refrigerant for controlling the admission of liquid refrigerant to said evaporator, means responsive to the temperatures at the inlet and outlet of said evaporator for producing an electric voltage proportional to the difference between the inlet and outlet temperatures, and means dependent upon said voltage for applying a boosting force to said actuating means.

2. In a refrigerating apparatus including an evaporator and means for supplying liquid refrigerant thereto and for withdrawing vaporized refrigerant therefrom, a thermostatic expansion valve for controlling the admission of liquid refrigerant to said evaporator in accordance with the superheat of the vaporized refrigerant withdrawn therefrom, said valve including opposed actuating elements responsive respectively to the pressure within said evaporator and the temperature of the refrigerant withdrawn therefrom, means responsive to the temperatures at the inlet and outlet of said evaporator for producing an electric voltage proportional to the difference between the inlet and outlet temperatures, and means dependent upon said voltage for applying a boosting force to said valve in the same direction as the resultant force on said elements.

3. In a refrigerating apparatus including an evaporator and means for supplying liquid refrigerant thereto and for withdrawing vaporized refrigerant therefrom, a thermostatic expansion valve including actuating means dependent upon the superheat of the vaporized refrigerant for controlling the admission of liquid refrigerant to said evaporator, means responsive to the temperatures at the inlet and outlet of said evaporator for producing an electric voltage proportional to the difference between the inlet and outlet temperatures, and means dependent upon a predetermined maximum value of said voltage for retaining said valve in its open position regardless of the condition of said actuating means.

4. In a refrigerating apparatus including an evaporator and means for supplying liquid refrigerant thereto and for withdrawing vaporized refrigerant therefrom, a thermostatic expansion valve including actuating means dependent upon the superheat of the vaporized refrigerant for controlling the admission of liquid refrigerant to said evaporator, means including thermocouples secured to said evaporator near the inlet and outlet thereof and connected in opposing relation in a series circuit for producing a voltage proportional to the difference between the inlet and outlet temperatures, and means dependent upon said voltage for applying to said actuating means a boosting force proportional to the difference between the inlet and outlet temperatures of said evaporator.

5. In a refrigerating apparatus including an evaporator and means for supplying liquid refrigerant thereto and for withdrawing vaporized refrigerant therefrom, a thermostatic expansion valve including actuating means dependent upon the superheat of the vaporized refrigerant for controlling the admission of liquid refrigerant to said evaporator, means including thermocouples secured to said evaporator near the inlet and outlet thereof and connected in opposing relation in a series circuit for producing a voltage proportional to the difference between the inlet and outlet temperatures, and means including an electronic amplifier responsive to said voltage for applying to said actuating means a boosting force proportional to the difference between the inlet and outlet temperatures of said evaporator.

6. In a refrigerating apparatus including an evaporator and means for supplying liquid refrigerant thereto and for withdrawing vaporized refrigerant therefrom, a thermostatic expansion valve for controlling the admission of liquid refrigerant to said evaporator in accordance with the superheat of the vaporized refrigerant withdrawn therefrom, said valve including opposed actuating elements responsive respectively to the pressure within said evaporator and the temperature of the refrigerant withdrawn therefrom, a pair of thermocouples one connected near the inlet and the other near the outlet of said evaporator for producing an electric voltage proportional to the difference between the inlet and outlet temperatures, and means including an electronic amplifier responsive to said voltage for applying to said valve a boosting force proportional to said difference in temperature throughout the normal range of operation of said valve.

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