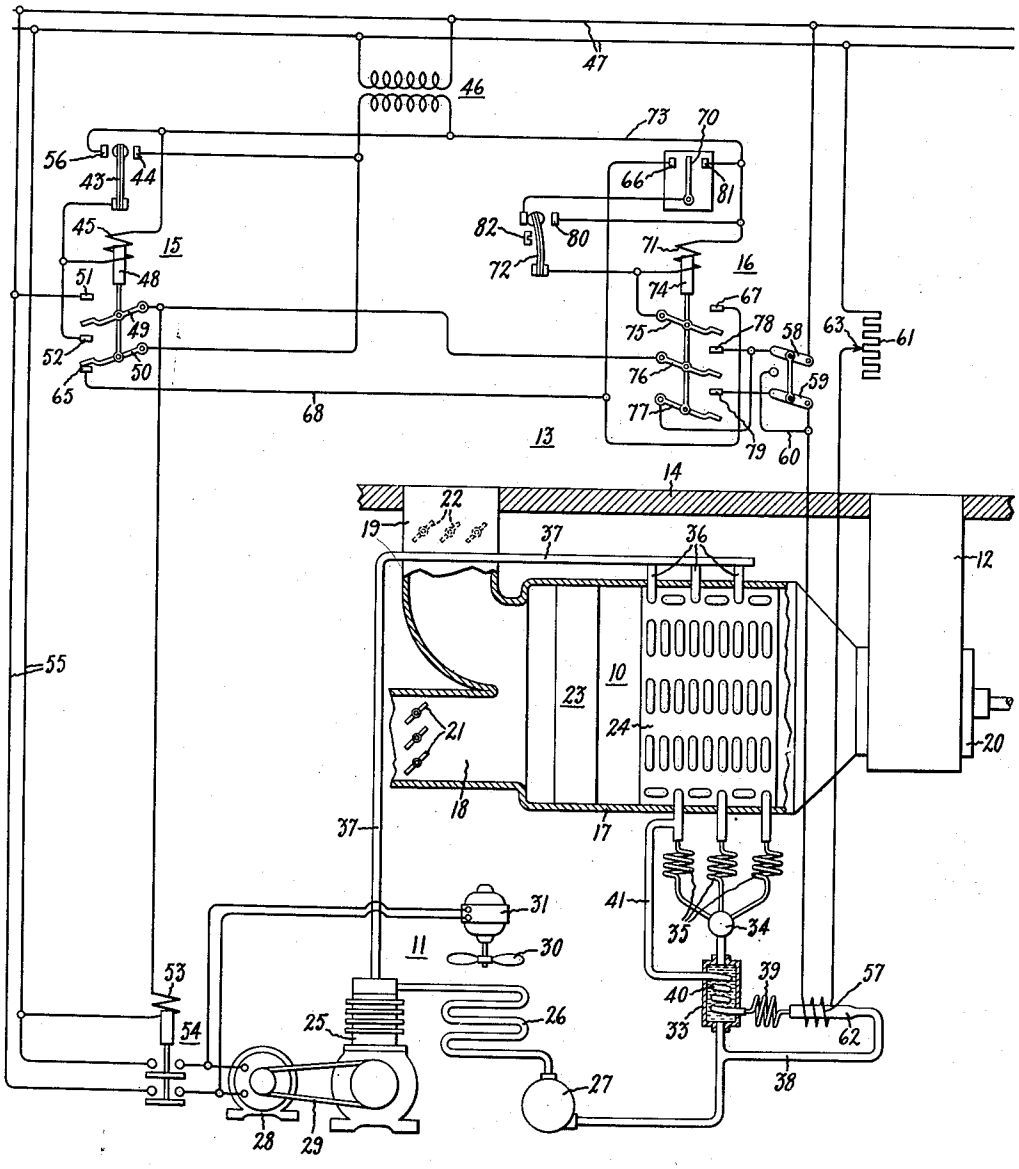
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FLUID COOLING SYSTEM

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## FLUID COOLING SYSTEM

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This invention relates to fluid cooling systems and particularly to such systems employing variable capacity refrigerant evaporators.

In fluid cooling systems, and particularly in air cooling systems, it is desirable to provide a control for adjusting the effective refrigerating capacity of the evaporator. For example, in an air conditioning system the evaporator may be employed to maintain a predetermined range of dry bulb or sensible temperatures in a room to be conditioned; however, when the relative humidity is high, it frequently happens that the dry bulb conditions will be satisfied before the relative humidity has been reduced to a value consistent with the desired comfort conditions. It is, therefore, desirable to operate the evaporator at reduced capacity in order to perform further latent cooling after the demand for sensible cooling has been satisfied. Various arrangements have been proposed for controlling refrigerant evaporators to provide variable effective refrigerating capacity. These systems have not been entirely satisfactory for all purposes from the standpoint of simplicity and reliability. Accordingly, it is an object of this invention to provide a fluid cooling system employing a refrigerant evaporator and including an improved arrangement for controlling the effective refrigerating capacity of the system.

It is another object of this invention to provide a fluid cooling system employing a refrigerant evaporator and a restrictor tube for controlling the flow of refrigerant to the evaporator and including an improved arrangement for controlling the flow of refrigerant through the restrictor tube.

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

In carrying out the objects of this invention, a compression type refrigerating system including an evaporator for cooling air is provided with restrictor tubes or capillaries to control the flow of refrigerant to the evaporator. In order to regulate the flow of liquid through the capillaries, a by-pass circuit is provided including a restrictor tube or capillary and an expander portion arranged in heat exchange with the liquid refrigerant flowing to the main capillary. The cooling capacity of the expander portion is thereby employed to subcool the liquid flowing from the capillaries, the refrigerant flowing from the expander portion to the evaporator where its remaining refrigerating capacity is available for air cooling. The flow of refrigerant through the by-pass circuit is controlled by applying heat to the inlet side of the by-pass capillary. The greater the amount of heating, the less the flow of refrigerant through the by-pass and the less the subcooling of the main refrigerant liquid supply. The supply of heat may be controlled either automatically upon a demand of the system or manually as desired.

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For a better understanding of this invention, reference may be had to the accompanying drawing, the single figure of which illustrates diagrammatically an air conditioning system provided with a refrigerating machine embodying this invention.

The air conditioning system illustrated in the drawing comprises an air cooling equipment 10 supplied with refrigerant from a condensing unit 11 and arranged to deliver cooled air through a discharge duct 12 into a room or enclosure 13, a portion of the walls of the room being indicated at 14. The temperature within the room is regulated by a thermostatic control 15 and, under certain conditions of operation, relative humidity is regulated by a humidity control 16. The cooling equipment 10 comprises a duct 17 having a fresh air inlet 18 and a return air inlet 19 connected to receive air from the room 13. The air is circulated through the duct 17 by operation of a blower 20 driven by a suitable motor (not shown). During the operation of the equipment the proportions of fresh and recirculated air are controlled by dampers 21 and 22 respectively, and the mixed air stream passes through a filter 23 and thence over an evaporator unit 24 and through the blower 20 to the discharge duct 12. The evaporator 24 is connected in a closed refrigerant circuit including a compressor 25, a condenser 26 and a receiver 27. The compressor 25 is driven by an electric motor 28 through a belt drive 29. When the compressor 25 is in operation hot compressed refrigerant gas is delivered to the condenser 26 where it is cooled by air circulated over the condenser by a fan 30 driven by an electric motor 31. The gaseous refrigerant in the condenser 26 is thereby cooled and liquefied, and the liquid refrigerant collects in the receiver 27 from which it flows through a heat exchanger 33 and a distributor 34 to a group of restrictor tubes or capillaries 35 connected to deliver refrigerant through three parallel paths or coils of the evaporator 24. The liquid refrigerant passing to the evaporator 24 is vaporized in the three coils, and vaporized refrigerant is

removed through three connections 36 and enters a suction line 37 through which it is returned to the compressor.

It will readily be understood that as air is circulated over the evaporator 24 by operation of the blower 26 it is cooled and delivered to the room, the heat removed from the air being absorbed by vaporization of liquid refrigerant in the evaporator and thereby being withdrawn by the compressor.

When the amount of liquid refrigerant supplied to the evaporator of a refrigerating system is decreased, there results a decrease in the effective area of the evaporator, that is in the area of the evaporator which is wetted by liquid refrigerant and therefore operates to provide substantial cooling of the air passing over its surface. As the quantity of refrigerant supplied to the evaporator is decreased, the balancing of the system for this new condition of operation results in a decrease in temperature of the refrigerant. Thus, the reduced effective surface operates at a lower temperature and, although the total sensible cooling may be substantially decreased, the dehumidifying capacity of the active portion of the evaporator may even be increased.

In the refrigerating system illustrated in the drawing, the rate of flow of refrigerant from the high side to the low side is determined by the dimensions of the restrictor tubes 35. The flow of liquid refrigerant through such tubes changes with changes in the temperature of the liquid, and the flow may be substantially impeded by the presence of gas formed by flashing or boiling of the liquid in the tube. In the system illustrated, the rate of flow of liquid through the tube is varied by varying the temperature of the liquid supplied to the tube in accordance with the requirements of the system to change the effective area of the evaporator surface.

In the arrangement disclosed, a portion of the liquid refrigerant from the receiver 27 may be circulated through a by-pass including an inlet duct 38, a restrictor tube 39, an evaporator coil 40 arranged within the heat exchanger 33 in heat transfer relationship with the liquid refrigerant, and an outlet connection 41 through which the by-passed refrigerant is conducted to the evaporator 24, it being shown as admitted to the first coil of the evaporator on the inlet side with respect to the air path in the duct 17. It will readily be apparent that the refrigerant circulated through the by-pass is expanded in the coil 40, and the refrigerating capacity thereof is employed to cool the liquid refrigerant in the heat exchanger 33, thus subcooling the refrigerant before it flows to the distributor 34.

The size of the capillary tubes 35 is selected so that with the full subcooling of the liquid refrigerant supplied to the tubes there will be practically no vaporization of the refrigerant in the tubes and therefore maximum supply of liquid will be secured. The tubes for this purpose are, as a rule, smaller than those employed with systems not provided with subcooling because subcooling affords greater liquid flow for a given size of tube. When the amount of subcooling is decreased, boiling or flashing of refrigerant in the tubes occurs and the rate of flow diminishes accordingly. This change in flow by change in the amount of subcooling of the liquid refrigerant is employed in the present system to vary the effective cooling capacity of the evaporator.

During the normal operation of the air conditioning system, should the temperature of the room 13 rise above a predetermined maximum desirable value, a bimetallic blade 43 of the thermostat 15 will move to the right and engage a stationary contact 44. This connects a coil 45 across the secondary of the transformer 46 the primary of which is connected across supply lines 47. Energization of the coil 45 raises a switch armature 48 to move switch arms 49 and 50 to their upper positions engaging contacts 51 and 52 respectively. Closing the switch 49 connects a coil 53 of a relay 54 across lines 55, which in turn are connected to the supply lines 47. The energization of the coil 53 actuates the relay 54 and connects motors 28 and 31 across the lines 55, thereby starting operation of the condensing unit. The operation of the refrigerating machine will continue even though the blade 43 moves away from the contact 44 because the lower switch 50 of the control 15, upon engagement with its contact 52, establishes a holding circuit for the coil 45 across the secondary of the transformer 46.

The operation of the refrigerating system will continue until the temperature of the air within the room 13 has been lowered to a predetermined value at which the blade 43 engages back contact 56, thereby shorting and deenergizing the coil 45 to allow the armature 48 to drop out and open the switches 49 and 50, thereby stopping operation of the system.

Throughout this normal operation of the system, the flow of liquid refrigerant through the by-pass circuit to provide cooling of the liquid refrigerant in the exchanger 33 is at full capacity, it being determined solely by the condition of operation of the refrigerating machine. Thus the maximum subcooling of the liquid refrigerant flowing to the capillaries 35 is available throughout normal operation. Should it be desired to decrease the effective refrigerating capacity of refrigerant flowing through the by-pass and thereby decrease the amount of subcooling of the liquid refrigerant, this can be accomplished by heating the liquid refrigerant supplied to the tube 39. An electric heater 57 is arranged to be energized by moving a pair of switch arms 58 and 59 to their lower positions, whereupon the arm 58 connects the heater 57 across the lines 47 through a lead 60 and a variable resistor 61. The heater 57 is mounted in heat exchange relationship with an enlarged portion 62 of the inlet conduit 38 so that heating of the liquid refrigerant flowing to the capillary tube 39 will decrease the capacity of the said capillary tube, hence decreasing the cooling effected by the evaporator portion 40 of the by-pass. The amount of heat may be adjusted by varying the position of a contact 63 on the resistor 61 and it is thus apparent that the amount of subcooling may be varied over a wide range and, if desired, sufficient heat may be supplied to the heater 57 to render the evaporator portion 40 ineffective to subcool the liquid in the heat exchanger 33.

In addition to the manual control just described, the humidity control 16 may be employed in order automatically to decrease the amount of subcooling of the liquid refrigerant when it is desired to continue operation of the evaporator 24 at reduced effective refrigerating capacity after the thermostat 15 has been satisfied. The humidity control 16 is effective when the switches 58 and 59 are moved to their upper position as shown in the drawing. It will be noted that the

lower switch arm 50 of the thermostat 15 in its lower position engages a stationary contact 65 and connects stationary contacts 66 and 67 of the humidity responsive device 16 to the left-hand side of the secondary of the transformer 46 through a conductor 68. Thus, should the thermostat 15 be in its position as shown on the drawing, the refrigerating machine may be operated by the humidity control 16. Should the relative humidity be higher than desired, a humidity responsive element 70 will move to the left and engage the contact 66, thereby establishing a circuit from the contact 66 through humidity responsive element 70 and a normally closed bimetallic strip 72 to a coil 71 and back through a lead 73 to the right-hand side of the transformer secondary. This energizes the coil 71, thereby raising a switch actuating armature 74 and moving switch members 75, 76 and 77 upwardly into engagement with the contact 67, a contact 78 and a contact 79 respectively. Engagement of the switch 75 and the contact 67 establishes a holding circuit for the coil 71, thereby maintaining the switches in their raised position even though the contact should be broken between the element 70 and the contact 66. Closing of the switch 76 by engagement of the contact 78 establishes a circuit from the upper side of the line 47 and the switch 58 through the switch 76 to the coil 53 of the switch 54, thereby starting the operation of the refrigerating machine. Engagement of the switch 77 with the contact 79 connects the upper side of the line 47 through the switch 58, the switch 77 and the switch 59 to the heater 57 thereby energizing the heater. The refrigerating machine, therefore, continues to operate to supply refrigerant to the evaporator 24 and cool the air passing through duct 17. The effective capacity of the evaporator 24, however, is reduced by the decrease in subcooling of the liquid refrigerant supplied to the evaporator and resulting from the heating of the liquid refrigerant in the bypass. This operation in response to the humidity control, therefore, reduces the effective refrigerating capacity of the evaporator and the sensible cooling may be no more than required to carry the normal heat load of the room; however, should the sensible cooling of the air continue under these reduced conditions until a predetermined minimum desirable value is reached, the bimetallic thermostat blade 72 will move to the right until it engages a stationary contact 80, thereby short circuiting the coil 71 to cause the switches 75, 76 and 77 to drop out and discontinue operation of the refrigerating machine. Should the relative humidity of the air in the room 13 be reduced to a predetermined desired value before the room temperature has been reduced to its minimum value as determined by the thermostatic blade 72, the humidity responsive element 70 will move to the right until it engages a stationary contact 81, whereupon the coil 71 will be short circuited through the element 70 and the bimetallic strip 72, thereby causing the switches to drop out and discontinue operation of the system. In order to insure stopping of the system when the humidity conditions are satisfied, the thermostat 72 is made of the two-position or snap-acting type so that the blade 72 does not break engagement with its left-hand contact until the temperature has reached a value such that it will move into engagement with its right-hand contact 80. The snap-acting characteristic of the thermostat has been illustrated diagrammatically as including a permanent magnet 82 for retaining the blade in its left-hand position until sufficient force has been built up to move it away from the magnet. It will readily be apparent, however, that effective dehumidification of the air may continue for a substantial period of time after the thermostat 15 has been satisfied and dehumidification will be interrupted only in the event the humidity has been reduced to a predetermined low value or in the event that the room temperature has been reduced to its permissible minimum.



From the foregoing it is readily apparent that a simple and easily adjustable arrangement has been provided for reducing the effective cooling capacity of the evaporator for the purpose of humidity control after the sensible temperature conditions have been satisfied. Although the invention has been illustrated in connection with a particular air conditioning system and control, other applications will readily be apparent to those skilled in the art. It is not, therefore, desired that the invention be limited to the details illustrated and described, and it is intended by the appended claims to cover all modifications within the spirit and scope of the invention.

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

1. A fluid cooling system comprising a refrigerating machine having a compressor and a condenser and an evaporator connected in a closed refrigerant circuit, means for circulating fluid to be cooled over said evaporator, a first restrictor tube for determining the rate of flow of liquid refrigerant from said condenser to said evaporator, and means arranged to control the temperature of the liquid refrigerant flowing to said tube from said condenser for varying the refrigerating capacity of said evaporator, said last-mentioned means comprising a by-pass around said tube between said condenser and said evaporator and including a second restrictor tube and a liquid refrigerant expanding portion, said expanding portion being arranged in heat exchange with the liquid refrigerant flowing to said first tube, said control means further including means for adjusting the rate of flow of refrigerant through said by-pass.

2. A refrigerating system including a compressor and a condenser and an evaporator connected in a closed refrigerant circuit, a restrictor tube for regulating the flow of liquid refrigerant from said condenser to said evaporator, an auxiliary cooling circuit by-passing said tube and including a second restrictor tube and an expansion conduit, said expansion conduit being connected in heat exchange relationship with said refrigerant circuit between said condenser and said first restrictor tube for cooling the liquid supplied to said first tube, and heating means for selectively supplying differing amounts of heat to the liquid refrigerant flowing to said second tube to adjust the amount of subcooling of the liquid supplied to said first tube and thereby vary the effective refrigerating capacity of said evaporator.

3. A refrigerating system including a compressor and a condenser and an evaporator connected in a closed refrigerant circuit, a restrictor tube for regulating the flow of liquid refrigerant from said condenser to said evaporator, an auxiliary cooling circuit by-passing said tube and including a second restrictor tube and an expansion conduit, said expansion conduit being connected to supply refrigerant to said evapora-

tor whereby the remaining cooling capacity of refrigerant flowing through said auxiliary circuit is available in said evaporator, said expansion conduit being connected in heat exchange relationship with said refrigerant circuit between said condenser and said first restrictor tube for cooling the liquid supplied to said first tube, and heating means for selectively supplying differing amounts of heat to the liquid refrigerant flowing to said second tube to adjust the amount of subcooling of the liquid supplied to said first tube and thereby vary the effective refrigerating capacity of said evaporator.

4. A refrigerating system including a compressor and a condenser and an evaporator connected in a closed refrigerant circuit, a restrictor tube for regulating the flow of liquid refrigerant from said condenser to said evaporator, an auxiliary cooling circuit by-passing said tube and including a second restrictor tube and an expansion conduit, said expansion conduit being connected in heat exchange relationship with said refrigerant circuit between said condenser and said first restrictor tube for cooling the liquid supplied to said first tube, an electric heater mounted in heat exchange relationship with a portion of said auxiliary circuit on the inlet side of said second restrictor tube, and selectively operable means for varying the energization of said heater to adjust the amount of subcooling of the liquid refrigerant supplied to said first tube and thereby vary the effective refrigerating capacity of said evaporator.



5. A refrigerating system including a compressor and a condenser and an evaporator connected in a closed refrigerant circuit, a restrictor tube for regulating the flow of liquid refrigerant from said condenser to said evaporator, means for conducting a fluid to be cooled into heat exchange relationship with said evaporator, an auxiliary cooling circuit by-passing said tube and including a second restrictor tube and an expansion conduit, said expansion conduit being connected in heat exchange relationship with said refrigerant circuit between said condenser and said first restrictor tube for cooling the liquid supplied to said first tube, heating means arranged in heat exchange relationship with said auxiliary circuit on the inlet side of said second tube, and means dependent upon a condition of the fluid to be cooled by said evaporator for varying the amount of heat supplied by said heating means.

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