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AIR CONDITIONING APPARATUS

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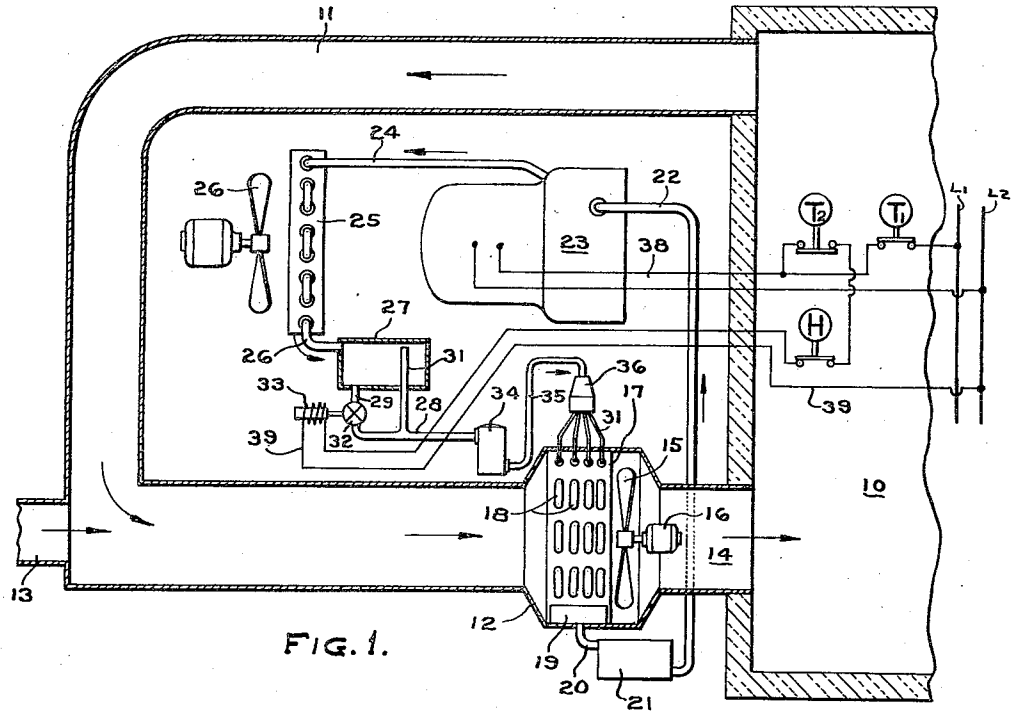

FIG. 1.

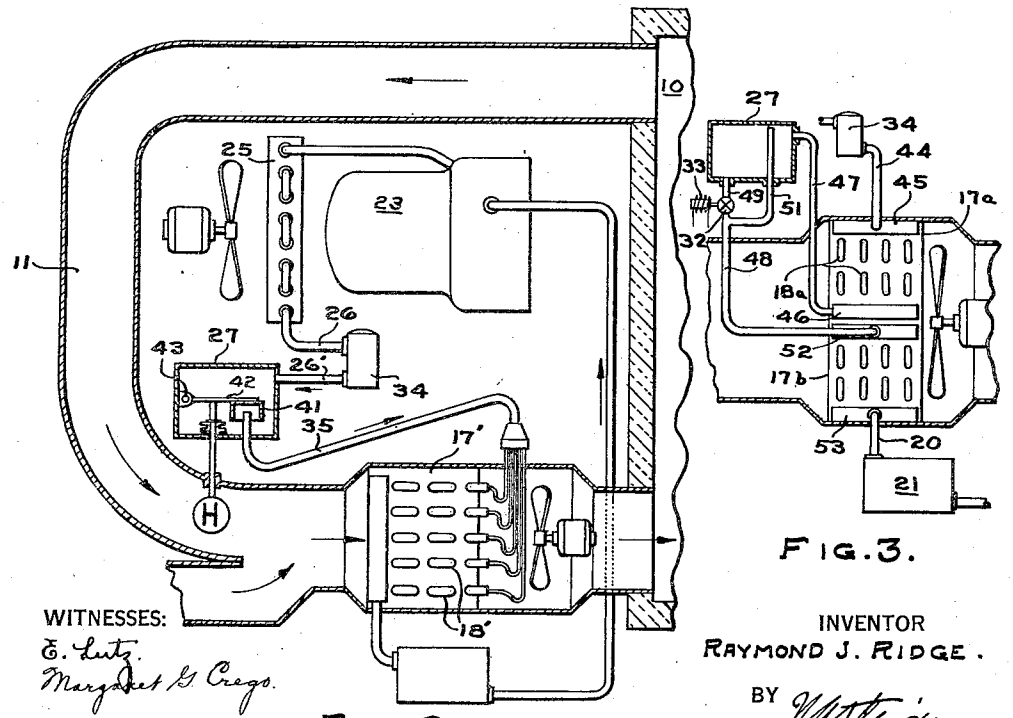

FIG. 2.

FIG. 3.

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AIR CONDITIONING APPARATUS

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9 Claims. (Cl. 62—6)

My invention relates to air conditioning apparatus, more particularly to apparatus for cooling and dehumidifying air for an enclosure, and it has for an object to provide improved apparatus.

Another object is to provide apparatus of relatively simple form whereby the humidity of the air in the enclosure, as well as the temperature thereof, may be maintained within desired limits.

A particular object is to provide air cooling apparatus comprising a compressor, in which the full capacity of the compressor is utilized whenever it is in operation and in which the portion of the cooling effect utilized to effect dehumidification may be increased when the demand for dehumidification increases.

In accordance with my invention, I provide an evaporator for cooling a stream of air, a compressor for withdrawing vaporized refrigerant from the evaporator, a condenser, and an expansion device. The refrigerating system is charged with a sufficient quantity of refrigerant so that substantially all of the evaporator may be supplied with liquid refrigerant and be effective to cool the air passing thereover. The apparatus is so designed that when all of the evaporator is supplied with liquid refrigerant, the air is not cooled greatly below its dew point, the cooling effect of the apparatus being applied mainly to the removal of sensible heat.

I also provide a chamber, preferably connected between the condenser and the evaporator, for selectively retaining therein a predetermined quantity of the condensed refrigerant, while permitting the condensed refrigerant in excess of such quantity to pass on to the evaporator. The liquid refrigerant supplied to the evaporator is thus so reduced in quantity as to supply only a portion of the evaporator therewith. The full capacity of the compressor, which is preferably of constant displacement, is applied to the portion of the evaporator that is supplied with liquid refrigerant, so that the said portion operates at reduced pressure and temperature. Consequently the air passing over said portion is cooled to a lower temperature and thereby dehumidified to a greater extent. The ratio of latent heat removal to sensible heat removal obtained in this case is greater than that obtained when the entire evaporator is supplied with liquid refrigerant.

The above and other objects are effected by my invention as will be apparent from the following description and claims taken in connection with the accompanying drawing, forming a part of this application, in which:

Fig. 1 is a diagrammatic view of air conditioning apparatus in accordance with my invention;

Fig. 2 is a similar view of a modified form; and

Fig. 3 is a partial diagrammatic view of a further modification.

Referring to the drawing in detail, I show an enclosure 10 to which cooled and dehumidified air is to be delivered. Air from the enclosure is conveyed through a duct 11 to an air conditioning chamber 12, and outdoor air is delivered through a duct 13 to the duct 11. From the chamber 12, the air is delivered to the enclosure 10 through a duct 14. Circulation of air is effected in any suitable manner, as by means of a fan 15 disposed in the chamber 12 and driven by a motor 16.

Within the chamber 12, there is provided an evaporator 17 for cooling and dehumidifying the air. In the illustrated embodiment, the evaporator 17 is of the type known as a dry evaporator and it has four coils 18, each coil comprising a plurality of horizontal tubes disposed in a common vertical plane and connected at their ends for flow of refrigerant from the uppermost tube successively to the lowermost tube. In accordance with common practice, these tubes are provided with fins or plates to increase the air cooling surfaces.

The lowermost tubes of the four coils are connected to a suction header 19, from which the vaporized refrigerant is conveyed through a conduit 20 to a reservoir 21, which is adapted to retain any unvaporized refrigerant. The vaporized refrigerant is then conveyed through a conduit 22 to the inlet of the compressor of a motor compressor unit 23. The connections just described provide substantially unrestricted communication between the outlet of the evaporator and the inlet of the compressor, which is preferably of constant displacement. The compressed refrigerant is conveyed from the unit 23 through a conduit 24 to a condenser 25. It is to be understood that any suitable form of condenser may be employed, the air cooled condenser 25, over which air is circulated by means of a fan 26, being shown merely by way of example.

The refrigerant condensed in the condenser 25 is conveyed through a conduit 26 to a chamber 27. A conduit 28 has one branch 29 connected to the bottom of the chamber 27 and a second branch conduit 31 communicating with the chamber 27 adjacent the top thereof. The branch 29 has a valve 32 actuated by a solenoid 33. The conduit 28 conveys the refrigerant to a high side float valve 34. It is then conveyed through a conduit 35 to a distributor fitting 36, from which it is

distributed to the several coils 18 through distributor or flow resistance tubes 37, sometimes termed capillary tubes. The tubes 37 are dimensioned to effect distribution of refrigerant in desired proportions among the several coils. In the present case, these tubes should be designed to supply successively smaller quantities to the several coils, the capacity of the several coils being successively smaller due to the successively lower temperature of the air passing over the coils in series.

The control mechanism for the apparatus includes line conductor L_1 and L_2. It further includes a thermostat T_1 which is adapted to close its contacts when the temperature in the enclosure 10 is higher than the value desired to be maintained therein, a humidostat H arranged to close its contacts when the humidity in the enclosure is higher than that desired to be maintained therein, and a thermostat T_2 arranged to open its contacts when the temperature in the enclosure reaches a still higher value at which it is desired to effect temperature reduction at the greatest possible rate without regard to dehumidification. The motor circuit 38 extends from line conductor L_1 through the contacts of thermostat T_1 and the motor of the compressor unit 23 to the line conductor L_2. The circuit 39 for energizing the solenoid 33 extends from line conductor L_1, through the contacts of thermostat T_1 in common with the circuit 38, then through the contacts of the thermostat T_2 and the humidostat H, and the solenoid 33 to the line conductor L_2.

OPERATION

Figure 1

Assume the temperature in the enclosure 10 to be above the value desired to be maintained therein while the humidity is within desired limits. The thermostat T_1 closes to energize the motor and initiate operation of the refrigerating system. The humidostat H opens its contacts to deenergize the solenoid 33 and open the valve 32. The refrigerating system now operates in the usual manner of such apparatus. Vaporized refrigerant is compressed by the compressor of the motor compressor unit 23, condensed in the condenser 25 and delivered to the chamber 27. Inasmuch as the valve 32 is open, the liquid refrigerant flows, as fast as it is condensed, from the chamber 27 through the branch conduit 29, the conduit 28, the float valve 34, the conduit 35, and the distributor 36, from which it is distributed through the tubes 37 to the several coils 18. It is vaporized in said coils, and the vaporized refrigerant is discharged from the several coils through the header 19 and conveyed to the compressor through the connections described above.

The refrigerating system is preferably charged with such quantity of refrigerant that there will be sufficient liquid refrigerant to extend throughout the length of the several coils 18. There may be some excess of liquid refrigerant discharged from the coils, which liquid refrigerant is retained in the reservoir 21 so as to avoid the admission of liquid refrigerant to the motor compressor unit. The air passing over the coils 18 is cooled to a desired extent, preferably slightly below its dew point. The degree of cooling, however, is such that most of the heat removed from the air is sensible heat and a smaller portion is latent heat of the moisture condensed therefrom.

Now assume that the humidity exceeds the value desired to be maintained in the enclosure 10 so that the humidostat H closes its contacts. Also assume that the temperature is only slightly above the desired value so that the contacts of the thermostat T_2 are in closed position. The circuit 39 is now completed to energize the solenoid 33 and close the valve 32. The condensed refrigerant entering the chamber 27 is now retained therein until the liquid level rises to the inlet of the branch conduit 31, whereupon further liquid flows through said branch conduit 31, the conduit 28, the float valve 34, and the several connections to the evaporator coils 18 as rapidly as it is condensed. Because of the liquid retained in the chamber 27, the quantity of liquid refrigerant supplied to the coils 18 is reduced to such an extent that only a portion of each coil, which may be approximately one half, is supplied with liquid refrigerant. In other words, the quantity of liquid refrigerant is such that, as the refrigerant has passed through one half of the coil, it is entirely vaporized. Due to the fact that the effective evaporator surface is reduced while the displacement of the compressor remains constant, the pressure of the refrigerant in the evaporator is reduced, so that the temperature in the portion of the evaporator containing liquid refrigerant is also reduced. Thus, the air passing over the portion of the evaporator containing liquid refrigerant is cooled to a substantially lower temperature, which is considerably below its dew point, so that it is dehumidified to a considerably greater extent than when all of the evaporator receives liquid refrigerant. The air passing over the lower half of the evaporator or the portion containing only vaporized refrigerant is only slightly cooled, that is, only to the extent that the vaporized refrigerant is able to absorb heat as sensible heat or superheat.

By decreasing the portion of the evaporator supplied with liquid refrigerant, the portion of the cooling effect of the apparatus applied to dehumidification is increased while the portion of the cooling effect applied to sensible heat removal is decreased. The latter is compensated by the prolonged period of operation necessary to bring the temperature to the desired value.

Upon decrease in humidity to the desired value, the humidostat H opens its contacts and the valve 32 is opened to supply liquid refrigerant to substantially the entire evaporator. Upon decrease in the temperature of the air in the enclosure to the desired value, a thermostat T_1 opens its contacts to terminate operation of the apparatus regardless of the humidity.

If the temperature in the enclosure 10 increases to an excessively high value, it may be desired to effect temperature reduction at the maximum possible rate regardless of the humidity. In such case, the thermostat T_2 is provided to open the circuit 39 and deenergize the solenoid 33. The valve 32 is opened, and substantially all of the evaporator is supplied with liquid refrigerant and is effective to cool the air and to dehumidify the same to some extent if its humidity is high. The apparatus operates in the manner first described above.

Figure 2

In Fig. 2, I show an embodiment of my invention in which the quantity of liquid refrigerant retained in the chamber 27 may be varied incrementally. The inlet end of the conduit 35 projects upwardly through the bottom of the chamber 27 into the interior thereof, and a tubular member 41, closed at its upper end, is arranged to telescope the upper end of the conduit 35.

In this embodiment, the chamber 27 is connected after the high side float valve 34 instead of ahead of it as in Fig. 1. The liquid refrigerant supplied from the high side float valve 34 through the conduit 26' to the chamber 27 is retained in the latter until the liquid level reaches the lower end of the tubular member 41, whereupon further liquid is caused to rise through the interior of said tubular member and then into the upper end of the conduit 35. Thus, the liquid level is always maintained at the lower end of the tubular member 41, and by raising or lowering the latter, the liquid level and the quantity of liquid refrigerant retained in the chamber 27 may be varied.

The tubular member 41 is mounted on a lever 42 pivoted at 43. The lever 42 is actuated directly by a humidostat H_2, whose humidity responsive element is disposed within the duct 11 and exposed to the air removed from the enclosure 10. It is arranged to raise the lever 42 and the tubular member 41 upon increase in the humidity, and to lower the same upon decrease in humidity.

In Fig. 2, I also show a modified form of evaporator 17'. The several coils 18' are arranged horizontally, parallel to the air stream, instead of transversely thereof as in Fig. 1. The refrigerant enters the coils on the side of the evaporator at which the air leaves and it flows through the successive tubes toward the side of the evaporator at which the air enters. In this case, substantially equal quantities of liquid refrigerant are supplied to the several coils. The action of the evaporator 17', so far as the present invention is concerned, is substantially the same as that of the evaporator 17 of Fig. 1. When the quantity of liquid refrigerant supplied to the evaporator coils is sufficient only to provide a portion of each coil thereof, said portion operates at reduced pressure and temperature to effect a greater degree of dehumidification of that portion of the air passing in contact therewith, while the remainder of each coil effects only a slight amount of cooling.

OPERATION

Figure 2

The refrigerating apparatus of Fig. 2 may be started and stopped in response to the temperature in the enclosure 10, to maintain the same substantially constant, in a manner similar to that of Fig. 1. Its operation is modified in response to the humidity of the air in the enclosure as follows: As the humidity increases, the humidostat H_2 moves the lever 42 upwardly, thereby increasing the quantity of liquid refrigerant retained in the chamber 27. The quantity of liquid refrigerant supplied to the evaporator 17' is reduced accordingly, so that a reduced portion of the evaporator is effective. The pressure and temperature of said portion is reduced, as will be understood from the explanation of Fig. 1, so that said portion operates to effect a greater degree of dehumidification of the air passing in contact therewith, while the remainder of the evaporator effects only a slight amount of cooling. Upon decrease in humidity, the lever 42 is moved downwardly to supply a greater quantity of liquid refrigerant to the evaporator. An increased portion of the evaporator is supplied with liquid refrigerant so that said portion operates at higher pressure and temperature. A greater portion of the air is cooled, and the degree of dehumidification is less since the air is not cooled to as low a dew point.

Figure 3

In Fig. 3, I show a further modification in which the evaporator comprises two elements 17*a* and 17*b* connected in series. The liquid refrigerant is conveyed from the high side float valve 34 through a conduit 44, directly to the inlet header 45 of the first element 17*a*. It is distributed in proper proportions in any suitable manner to the several coils 18*a* and then conveyed through a suction header 46 and a conduit 47 to the chamber 27. A conduit 48 has one branch 49 connected to the bottom of the chamber 27 and a second branch conduit 51 communicating with the chamber 27 adjacent the top thereof. The branch conduit 49 is provided with a valve 32 actuated by a solenoid 33, as in Fig. 1. The conduit 48 conveys refrigerant to the inlet header 52 of the second evaporator element, 17*b*, from which the liquid refrigerant is distributed in proper proportions to the several coils of the element 17*b*. The vaporized refrigerant is then conveyed through a suction header 53 and the conduit 20 to the reservoir 21 as in Fig. 1.

The refrigerating system of the embodiment shown in Fig. 3 is charged with such quantity of refrigerant that the coils of both evaporator elements are supplied with liquid refrigerant when the valve 32 is open. At such time, the mixture of liquid and gaseous refrigerant discharged from the float valve 34 first passes through the coils of the element 17*a*, in which a portion of the liquid refrigerant is vaporized. The mixture then flows to the chamber 27, and, as the valve 32 is open, both liquid and gaseous refrigerant pass on through the branch conduit 49 and the other connections to the evaporator element 17*b*, in which the remainder of the liquid refrigerant is vaporized. The evaporator elements operate at relatively high pressure and temperature, and remove mainly sensible heat from the air stream passing over the same.

When the valve 32 is closed, all of the liquid refrigerant entering the chamber 27 is retained therein, the gaseous refrigerant passing through the branch conduit 51 to the evaporator element 17*b*. Only the evaporator element 17*a* now contains liquid refrigerant and it operates at reduced pressure and temperature to increase the portion of cooling effect applied to dehumidification. The operation in other respects is the same as that of Fig. 1, and it may be controlled in the same way.

From the above description, it will be seen that I have provided relatively simple and reliable mechanism for controlling the operation of the apparatus so as to maintain the humidity as well as the temperature of the air within desired limits.

While I have shown my invention in several forms, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various other changes and modifications without departing from the spirit thereof, and I desire, therefore, that only such limitations shall be placed thereupon as are imposed by the prior art or as are specifically set forth in the appended claims.

What I claim is:

1. In air conditioning apparatus, a refrigerating system comprising an evaporator for cooling and dehumidifying a stream of air passing thereover, a compressor, a condenser, means for con-

veying liquid refrigerant from the condenser to the evaporator and for reducing the pressure thereof and means responsive to increase in humidity for decreasing the effective refrigerant charge in the system to the extent of depriving a portion of the evaporator of liquid refrigerant, whereby the remaining portion operates at reduced temperature to effect a greater degree of dehumidification of the air passing thereover.

2. In air conditioning apparatus, a refrigerating system comprising an evaporator for cooling and dehumidifying a stream of air passing thereover, a compressor, a condenser, an expansion device, and means operable independently of said expansion device for selectively retaining in a portion of the system other than the evaporator a definite quantity of liquid refrigerant such that a portion of the evaporator is deprived of liquid refrigerant, whereby the remaining portion operates at reduced temperature to effect a greater degree of dehumidification of the air passing thereover.

3. In air conditioning apparatus, a refrigerating system comprising an evaporator for cooling and dehumidifying a stream of air passing thereover, a compressor, a condenser, an expansion device, and means operative in response to high humidity to retain in a portion of the refrigerating system other than the evaporator a definite quantity of liquid refrigerant such that a portion of the evaporator is deprived of liquid refrigerant, whereby the remaining portion operates at reduced temperature to effect an increased degree of dehumidification of the air passing thereover.

4. A refrigerating system for cooling and dehumidifying air comprising an evaporator, means for passing air over said evaporator, a compressor, a condenser, a high side float valve for controlling flow of liquid refrigerant from the condenser to the evaporator, a chamber connected between the condenser and the evaporator, and means responsive to high humidity for retaining in said chamber a quantity of liquid refrigerant such that only a portion of the evaporator contains liquid refrigerant, whereby said portion operates at reduced pressure and temperature to effect a greater degree of dehumidification of the air passing thereover.

5. In air conditioning apparatus, a refrigerating system including an evaporator for cooling a stream of air, and means for selectively retaining, in a portion of the refrigerating system other than the evaporator, a predetermined quantity of refrigerant such that only a portion of the evaporator contains liquid refrigerant, whereby said latter portion may operate at reduced pressure and temperature to effect a greater degree of dehumidification of the air passing thereover.

6. In air conditioning apparatus, a refrigerating system including an evaporator for cooling a stream of air, a compressor, a condenser, a chamber, and means for selectively retaining in the chamber a predetermined quantity of liquid refrigerant while permitting additional liquid to pass on to the evaporator for operation at relatively low temperature, or permitting said predetermined quantity to flow to the evaporator for operation at higher temperature.

7. In apparatus for cooling a body of air and for controlling the moisture content thereof, the combination of an evaporator, a condenser, a constant displacement compressor for withdrawing vaporous refrigerant from the evaporator and for delivering it at relatively high pressure to the condenser for liquefaction, means for withholding variable quantities of refrigerant from circulation whereby the quantity of refrigerant present in the evaporator is varied, means for conveying the body of air in heat transfer relation with the refrigerant in the evaporator, and humidity responsive means for controlling the amount of withheld refrigerant independently of conditions of the evaporated refrigerant.

8. In air conditioning apparatus, a refrigerating system comprising an evaporator for cooling and dehumidifying a stream of air passing thereover, a compressor, a condenser, an expansion device of a type which permits liquid refrigerant to flow therethrough as rapidly as it is received by the expansion device, and means for selectively retaining in a portion of the system other than the evaporator a quantity of liquid refrigerant such that a portion of the evaporator is deprived of liquid refrigerant, whereby the remaining portion operates at reduced temperature to effect a greater degree of dehumidification of the air passing thereover.

9. In air conditioning apparatus, a refrigerating system comprising an evaporator for cooling and dehumidifying a stream of air passing thereover, a compressor, a condenser, an expansion device of a type which permits liquid refrigerant to flow therethrough as rapidly as it is received by the expansion device, and means operative in response to a predetermined high humidity condition of air to retain in a portion of the refrigerating system other than the evaporator a quantity of liquid refrigerant such that a portion of the evaporator is deprived of liquid refrigerant, whereby the remaining portion operates at reduced temperature to effect an increased degree of dehumidification of the air passing thereover.

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