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AIR CONDITIONING SYSTEM

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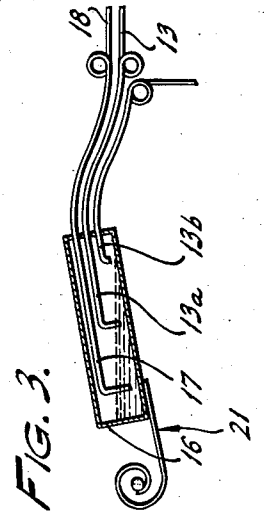


FIG. 3.

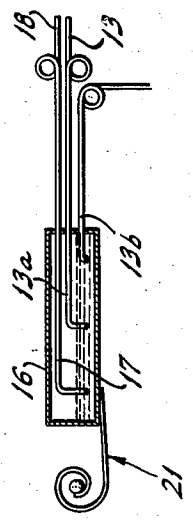


FIG. 2.

FIG. 1.

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AIR CONDITIONING SYSTEM

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10 Claims. (Cl. 62—3)

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This invention is concerned with refrigeration apparatus and, more partcularly, relates to control of the air cooling and dehumidification functions of such apparatus.

Broadly, the invention has for its primary object the provision of control, or modulation, of the capacity of an air conditioner or other refrigerating machine in such manner that the temperature of ambient or circulating air is maintained within a desired range, without undue sacrifice of the capacity of the machine to effect the transfer of latent heat which results in condensation of undesired moisture present in the circulating air.

As is now well known in air conditioning practice, maintenance of a conditioned space within the so-called "comfort zone" involves not only control of the air dry bulb temperature, but also limitation of the relative humidity prevailing within said space. For example, under summer cooling conditions, the comfort zone is generally regarded as covering a range of relative humidities from about 70% to about 30%, the permissible comfort zone temperatures ranging from 68° to 78°, under the 70% condition, and from 72° to 85°, at the 30% condition. Under high humidity conditions commonly encountered in climates where room cooling is desirable, "pull down" of the air temperature to an acceptable value necessarily results in a very substantial increase in relative humidity of the air, and it will therefore be appreciated that removal of moisture from the air is essential to comfort. A relatively wide range of psychrometric conditions may exist in practice, and control of the capacity of the air conditioning machine (as respects transfer of both sensible and latent heat) is therefore essential if the space being conditioned is to be kept in the comfort zone.

At times, particularly when the apparatus is being operated to cool a bedroom at night, the dry bulb temperature of the circulating air may drop below the acceptable minimum and it is then desirable to modulate the capacity of the machine in such a way as to restore the desired temperature condition.

In large installations such modulation can conveniently be provided by controlling the amount of moisture in the air, to offset changes in cooling capacity. Similarly in large installations refrigerating effect can also conveniently be modulated by varying the number of compressor cylinders effective to pump refrigerant, or by manipulating dampers to regulate air flow. Not uncommonly some regulation of refrigerating effect has been

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achieved by varying the speed of the compressor.

While control of both temperature and humidity conditions is also a problem in the case of single room package type air conditioners, the foregoing solutions are not applicable for a variety of reasons, including cost considerations. Most single room air conditioners utilize a compressor having only one cylinder and it is therefore apparent that modulation of capacity by varying the number of cylinders is not feasible. Cycling the motor compressor has also not proven to be a practical solution. The rapid increase in humidity which usually takes place during periods of idleness of the compressor may cause the humidity to reach a value exceeding comfort zone limits, even though cycling can readily be utilized to maintain the dry bulb temperature within a satisfactory range. Further, the variation in sound level which results from cycling the unit is highly objectionable, especially in bedroom applications.

Attempts have been made to meet the foregoing difficulties and to provide satisfactory capacity modulation of air conditioning equipment of the simpler type to which this invention has particular reference, and heretofore these attempts have usually involved provision of means for varying the operation of the air conditioning machine in such a way that the temperature of the entire evaporator is raised to a higher value in response to a predetermined reduction in the temperature of the circulating air. However this expedient is also unsatisfactory, in view of the fact that there is no longer sufficient limitation of humidity, and for this reason, it is not possible to meet the comfort zone conditions. The truth of this will be recognized when it is understood that increasing the temperature of the entire evaporator limits the capacity of the evaporator to effect transfer of latent heat and, as a consequence, the relative humidity may rise to an excessively high value. Attempts have also been made to meet this problem by utilizing machines having two separate refrigerating units, operation of one of which can be discontinued when reduction in total capacity is desired. Its relatively high cost renders this type of apparatus undesirable, and it is also to be noted that discontinuation of operation of one of the units results in variation in the sound level of the machine. As pointed out above, such variation is objectionable.

With the foregoing in mind, it is to be emphasized that the present invention provides for modulating the capacity of refrigerating machines in

such manner that the total air cooling capacity of the evaporator is reduced, when the temperature of the circulating air falls to a predetermined value, while yet continuing to maintain a portion of the evaporator at a temperature sufficiently low to result in substantial condensation of moisture present in the air. It is particularly noteworthly that these advantageous results are achieved in a very simple manner and by the use of only a single room-cooling evaporator element operating at a single pressure throughout.

In the achievement of the foregoing general ends the invention provides, in novel combination with the elements of an air conditioning system of known type, an auxiliary refrigeration circuit or system including: a tank or receiver adapted to receive liquid refrigerant flowing from the condenser; and associated restrictor and evaporator portions. Said tank and portions are connected in series circuit with the compressor, and the evaporator portion of said auxiliary system is disposed in high heat exchange relation with the high pressure side of the main refrigeration system. Means is provided for causing a portion of the liquid refrigerant derived from the condenser to flow through the auxiliary system, when reduction in total cooling capacity of the main evaporator is desired, with the result that the main evaporator element is deprived of a certain amount of the liquid refrigerant which would normally flow thereto and, as a consequence, only a portion of the main evaporator is supplied with liquid refrigerant and remains effective for cooling purposes. The portion which remains effective, however, continues to operate at a temperature approximately equal to the normal, unmodulated temperature of the overall evaporator, since no change occurs in the suction pressure of the machine, and this temperature is, of course, sufficiently low to result in substantial condensation of moisture present in the circulating air. The extent of the evaporator portion which is deprived of liquid refrigerant may be varied to any desired degree and, in the illustrated embodiment, this variation is advantageously controlled by movably or tiltably mounting the aforesaid tank or receiver, which tank is connected with both the main evaporator element and the evaporator portion of the auxiliary system. Tilting of the tank provides selective distribution of the condensed refrigerant between the said evaporator element and said evaporator portion.

The manner in which the objects and advantages of the invention may best be achieved will be more clearly understood from a consideration of the following description, taken in conjunction with the accompanying drawing, in which:

Figure 1 is a diagrammatic representation of an air conditioning machine embodying the modulating apparatus of my invention, the aforesaid adjustable tank or receiver being shown in section; and,

Figures 2 and 3 illustrate the tank in positions of adjustment other than that shown in Figure 1.

Now making more detailed reference to the drawing, there is diagrammatically illustrated an air conditioning or refrigerating system including a pair of heat exchangers **10** and **11** which, as shown, are of known finned coil type. A compressor **12** is connected in series flow circuit with said heat exchangers through the agency of suitable conduits including suction and discharge passages which appear in the drawing at **14** and **15**, respectively, and a capillary type restrictor, portions of which are shown at **13**, **13***a*, **13***b* and **13***c*. As will be understood, the suction line **14** and portions of the capillary tube **13** may be placed in heat exchange relation, but such disposition of these elements has been omitted from the drawing in the interest of simplicity in illustration.

In particular accordance with the present invention there is included a tank or receiver **16** within which is disposed both section **13***a* of the aforesaid capillary tubing through which liquid flows to the tank, and a similar section or connection **13***b*. The latter provides for outflow of liquid from the tank and toward the evaporator element **10**, through capillary tube **13***c*. Each of these sections terminates in a downwardly presented opening freely communicating with the interior of the tank or receiver, and it will be observed that an additional section of tubing of capillary size extends within the receiver. This additional section, illustrated at **17**, is also provided with a downwardly presented opening communicating with the space within the receiver, and forms an extension of a capillary passage **18** connected with a conduit a portion of which (shown at **19**) is disposed in heat exchange relation with the discharge line **15**, and another portion of which (illustrated at **14***a*) provides an auxiliary suction line returning to the compressor **12**. As will be understood, the conduit portion **19** constitutes the evaporator portion of the auxiliary circuit mentioned hereinabove. Further and more detailed reference to the receiver and the manner in which it is mounted will be made hereinafter.

The illustrated embodiment further includes switching apparatus shown diagrammatically at **20** and through the agency of which the motor of compressor **12** may be placed across the line L. As will be understood, when the machine is intended for use as an air conditioner, provision would be made for forcing air over the heat exchangers or coils **10** and **11**, and to this end suitable fans and motors are commonly employed. These elements of the apparatus have been omitted from the drawing, since illustration and description thereof are not necessary to an understanding of the present invention. It is, however, to be understood that air to be cooled and dehumidified is freely circulated in heat exchange relation with the evaporator element **10** and, for purposes which will be set forth in what follows, in heat exchange relation with thermo-sensitive means which adjustably supports the tank or receiver **16**.

While a showing of the air conditioner cabinet has also been omitted, it will be appreciated that a cabinet would be provided having partition means serving to divide the same into separate chambers housing the evaporator **10** and the condenser **11**. A dashed line appears in Figure 1, and the evaporator lies to the left thereof. As is apparent from the legend applied to the drawing this portion of the apparatus is disposed upon the "indoors" side of the dashed line. The condenser and preferably the compressor are, as indicated, disposed out-of-doors.

The construction of the above-described machine as respects the general organization of the main refrigeration circuit, the cabinetry and the control circuitry, is conventional in nature, and its operation need not be considered in further detail herein except insofar as the elements thereof cooperate with and are affected by the novel capacity modulating means which includes

the aforesaid tank or receiver 16, and which means will now be more fully considered.

As mentioned above, the receiver 16 is mounted for tilting movements, in order to provide feed of the liquid refrigerant selectively to different portions of the circuit, and preferably the receiver is adjustably supported by a thermo-sensitive element which, as shown, take the form of strip 21 of bi-metallic material, said strip being secured to the receiver 16 and having a spirally configured portion 22 the inner convolution of which is fixedly secured to a stud 23. The spirally configured strip portion is disposed adjacent the evaporator element 10 and in the path of air flowing in heat exchange relation with said evaporator element. As will be understood without further description, changes in air temperature cause the lower end of the strip 21 to be raised or lowered. Thus the tank is so mounted as to be tilted or adjusted in response to the temperature of the air passing the evaporator element 10. As will more clearly appear in what follows, when this temperature has fallen to a predetermined lower value the strip 21 tilts or rotates the receiver 16 to a position such that a controlled amount of liquid refrigerant flowing to said receiver by-passes the main evaporator element 10 and returns to the compressor through the auxiliary refrigeration system, including the evaporator portion 19. When the desired air temperature is re-established the tank is, of course, returned to a position such that all or the major part of the liquid refrigerant is delivered to the main evaporator. It is to be understood that while such automatic control of the position of the receiver is preferred, the invention also contemplates use of manually operable means, or other expedients, for varying the position of the receiver.

To accommodate the tilting movements of the receiver, the restricted passages which extend thereinto have sufficient flexibility to permit free movement of the receiver without interfering with the flow of refrigerant through the passages. Such accommodation can conveniently be provided by including a flexible loop of tubing, as illustrated in the drawing.

Although it is not essential that all of the tubing interconnecting the condenser, receiver and the two evaporators 10 and 19, be of the type commonly known in this art as "capillary" tubing, it is preferred that such be the case, since use of such tubing represents a simple way of preventing any considerable loss in capacity due to gas flowing through the tubing path not in use. Preferably the tubing sections are of such internal diameter and length that the restriction from the receiver 16, to the evaporator, and thence to the suction side of the compressor, is approximately equal to the restriction presented by the circuit from the said receiver, to the auxiliary evaporator portion 19, and thence to the suction side of the compressor through conduit 14a. It is, of course, the physical restriction rather than the effective restriction which is preferably so proportioned, it being understood that the amount of refrigerant, by weight, which can pass through one of the two parallel circuits in the liquid phase is many times the quantity of refrigerant by weight, which will pass through the other path in the gaseous phase.

In operation the receiver 16 may occupy any angular position between the limiting positions illustrated in Figures 1 and 3, but consideration of the operation of the apparatus with respect to three positions of the receiver will suffice to illustrate the manner in which the equipment functions. First making reference to Figure 1, it will be seen that the receiver 16 is shown in that figure as occupying a position in which all of the liquid refrigerant flowing into said receiver, through the connection 13a, passes to the main evaporator element 10 through connection 13b and the capillary tubing 13c, which is interposed between said connection and the evaporator. Thus Figure 1 is illustrative of the position which the receiver occupies when the main evaporator element is operating at maximum capacity. When the receiver is so positioned the connection 13b is immersed in liquid refrigerant, as shown, and the connection 17 which communicates with capillary tubing 18 and the auxiliary evaporator portion 19, is disposed above the level of liquid refrigerant within the receiver, with the result that the receiver operates as a flash gas separator, returning only gas to the compressor through the auxiliary circuit.

The position of the receiver which results in minimum capacity at the main evaporator is illustrated in Figure 3, and this will be understood to be the position in which substantially all of the liquid refrigerant delivered to the receiver returns to the compressor through the alternate or auxiliary circuit and only gas traverses the evaporator, since the connection 13b is then disposed above the level of liquid within the receiver. The liquid passing through the tubing 17 and 18 toward the compressor 12 is returned to the gaseous state, by virtue of flowing through evaporator portion 19, wherein, by virtue of heat exchange between the said portion and the warm gaseous refrigerant flowing through the conduit 15 of the main refrigeration circuit, the liquid emitted from the capillary tube 18 is re-evaporated and returned to the compressor through suction conduit portion 14a.

Any quantity of refrigerant which is caused to flow through the auxiliary circuit, by-passing the main evaporator, represents a direct reduction in the effective capacity of the main evaporator, and the significance of this will be appreciated when it is understood that the receiver may occupy intermediate positions, one of which is illustrated in Figure 2, in which both of the parallel paths are supplied with liquid refrigerant. Under such a condition, due to the substantial equality of the restriction of the two parallel circuits, there results about a 50% reduction in the cooling capacity of the main evaporator. However, and importantly, passage of the liquid through the auxiliary circuit does not result in raising the suction pressure to which the main evaporator is subjected and, therefore, as large a portion of said main evaporator as is supplied with liquid refrigerant continues to operate at a surface temperature about as low as is obtained under the normal, unmodulated condition illustrated in Figure 1. The importance of this in providing the necessary continuance of removal of moisture from the air will be understood without restatement, and is to be contrasted with arrangements hitherto known in which throttling, and the like, resulted in an increased pressure in the main evaporator with consequent undesirable increase in the surface temperature thereof.

Thus, and in the light of the foregoing description, it will be understood that the present invention provides air conditioning or refrig-

erating equipment of very simple type in which the total air cooling capacity of the main evaporator element may be controlled automatically, while yet maintaining a portion of said evaporator element at a temperature sufficiently low to continue substantial condensation of excess moisture present in the circulating air.

While a preferred structural embodiment has been illustrated and described, it is to be borne in mind that said embodiment is susceptible of modification, without departing from the spirit of this invention. For example, the receiver **16** may readily be mounted for movements other than tilting movements. Further, it is to be understood that, in the broader aspect, the invention is characterized by providing for flow of refrigerant through parallel circuits of approximately equal restriction, in order that the flow of refrigerant by volume may be substantially the same in the two circuits under any condition of operation, coupled with means for selective distribution of the liquid component of the refrigerant between the two parallel circuits. In this aspect of the invention, a variety of flow control means may be utilized and are contemplated. However it will be recognized that the invention contemplates such changes and modifications as properly come within the scope of the appended claims.

I claim:

1. In refrigeration equipment: a main refrigeration system including compressor, condenser, restrictor and evaporator elements so connected in series flow circuit that evaporation of refrigerant occurs in said evaporator element with consequent cooling of an ambient medium; an auxiliary refrigeration system; and apparatus for adjusting the heat exchange capacity of said evaporator element, including a movably mounted receiver to which is delivered liquid refrigerant flowing from said condenser element, said receiver being provided with a pair of outlet passages one of which communicates with said evaporator element and the other of which communicates with said auxiliary system, movement of said receiver serving to control the supply of liquid refrigerant to the said outlet passages to provide selective distribution of the condensed refrigerant between said evaporator element and said auxiliary system.

2. In refrigeration equipment: a main refrigeration system including compressor, condenser, restrictor and evaporator elements so connected in series flow circuit that evaporation of refrigerant occurs in said evaporator element with consequent cooling of an ambient medium; an auxiliary refrigeration system; apparatus for adjusting the heat exchange capacity of said evaporator element, including a movably mounted receiver to which is delivered liquid refrigerant flowing from said condenser element, said receiver being so connected with said evaporator element and with said auxiliary system that movement of said receiver provides selective distribution of the condensed refrigerant between said evaporator element and said auxiliary system; and means responsive to the temperature of the said ambient medium to effect movement of said receiver.

3. Refrigeration equipment in accordance with claim 2, and further characterized in that said means comprises a thermo-sensitive device having a portion disposed and adapted to sense the temperature of the ambient medium and another portion movable in response to changes in temperature of said medium and adapted to effect corresponding movement of said receiver.

4. In refrigeration equipment: a main refrigeration system including compressor, condenser, restrictor and evaporator elements so connected in series flow circuit that evaporation of refrigerant occurs in said evaporator element with consequent cooling of an ambient medium; an auxiliary refrigeration system; and apparatus for adjusting the heat exchange capacity of said evaporator element, including a tiltable receiver to which is delivered liquid refrigerant flowing from said condenser element, said receiver being so connected with said evaporator element and with said auxiliary system that tilting of said receiver provides selective distribution of the condensed refrigerant between said evaporator element and said auxiliary system.

5. In refrigeration equipment: a main refrigeration system including compressor, condenser, restrictor and evaporator elements so connected in series flow circuit that evaporation of refrigerant occurs in said evaporator element with consequent cooling of an ambient medium; an auxiliary system including an evaporator portion in communication with the suction side of said compressor element; and apparatus for adjusting the heat exchange capacity of said evaporator element, including a tiltable receiver to which is delivered liquid refrigerant flowing from said condenser element, said receiver being provided with a pair of spaced outlet passages one of which communicates with said evaporator element and the other of which communicates with said evaporator portion, tilting of said receiver serving to control the supply of liquid refrigerant to the said outlet passages to provide selective distribution of the condensed refrigerant between said evaporator element and said evaporator portion.

6. Refrigeration equipment in accordance with claim 5, and further including means responsive to the temperature of the ambient medium to effect tilting of said receiver.

7. In air conditioning equipment, means for circulating liquid and gaseous refrigerant, a pair of refrigerant flow circuits connected in parallel with said means and each including an evaporator, said circuits presenting approximately equal restriction whereby, in response to operation of said circulating means, approximately equal quantities of refrigerant, by volume, flow through each of said circuits, and means providing selective distribution of liquid and gaseous components of the circulating refrigerant between said two circuits, said last means comprising a movably mounted receiver disposed to receive refrigerant from said circulating means and having a pair of outlet passages each of which communicates with a corresponding one of said circuits, movement of said receiver serving to control the supply of liquid and gaseous refrigerant to the said outlet passage to provide the stated selective distribution.

8. Air conditioning equipment in accordance with claim 7, and further including thermo-sensitive means responsive to the temperature of air cooled by one of said evaporators and adapted to effect adjustment movements of said receiver in accordance with the temperature of such air.

9. In refrigeration equipment, a main refrigeration system including compressor, condenser, restrictor, and evaporator elements so connected in series flow circuit that condensation of re-

frigerant occurs in said condenser element and evaporation of refrigerant occurs in said evaporator element with consequent cooling of ambient air, and apparatus for reducing the total air cooling capacity of said evaporator element while yet maintaining a part of said element at a temperature sufficiently low to result in substantial condensation of moisture present in the ambient air, said apparatus comprising: an auxiliary refrigeration system in circuit with said compressor element and including an evaporator connected in parallel with said main refrigeration system; and means including a chamber providing for volatilization of a portion of the liquid refrigerant discharged from said condenser element, and also providing for selective and controllable delivery, to said evaporator element and to the evaporator portion of said auxiliary system, of the gaseous and liquid refrigerant components available at said means.

10. In refrigeration equipment: a main refrigeration system including compressor, condenser, restrictor and evaporator elements so connected in series flow circuit that evaporation of refrigerant occurs in said evaporator element with consequent cooling of an ambient medium; an auxiliary refrigeration system presenting restriction approximately equal to the restriction of said main refrigeration system; and apparatus for adjusting the heat exchange capacity of said evaporator element, including a movably mounted receiver to which is delivered liquid refrigerant flowing from said condenser element, said receiver being so connected with said evaporator element and with said auxiliary system that movement of said receiver provides selective distribution of the condensed refrigerant between said evaporator element and said auxiliary system.

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