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AIR CONDITIONING SYSTEM WITH DEHUMIDIFIER AND REHEATER

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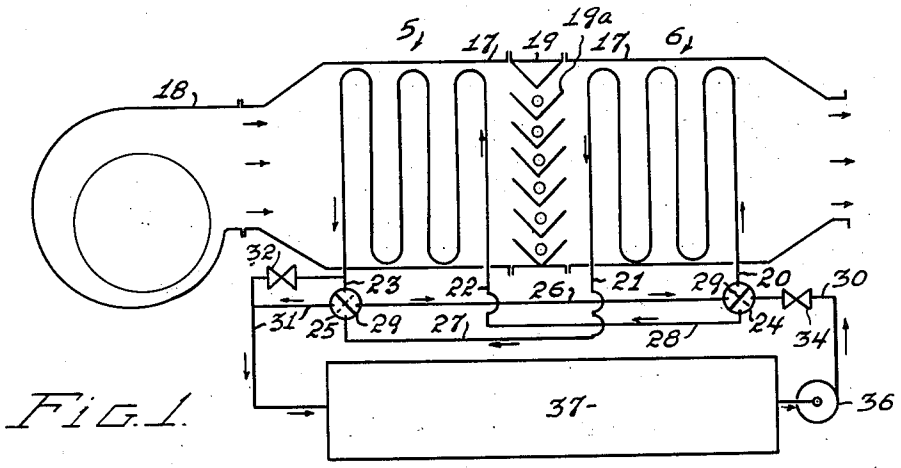
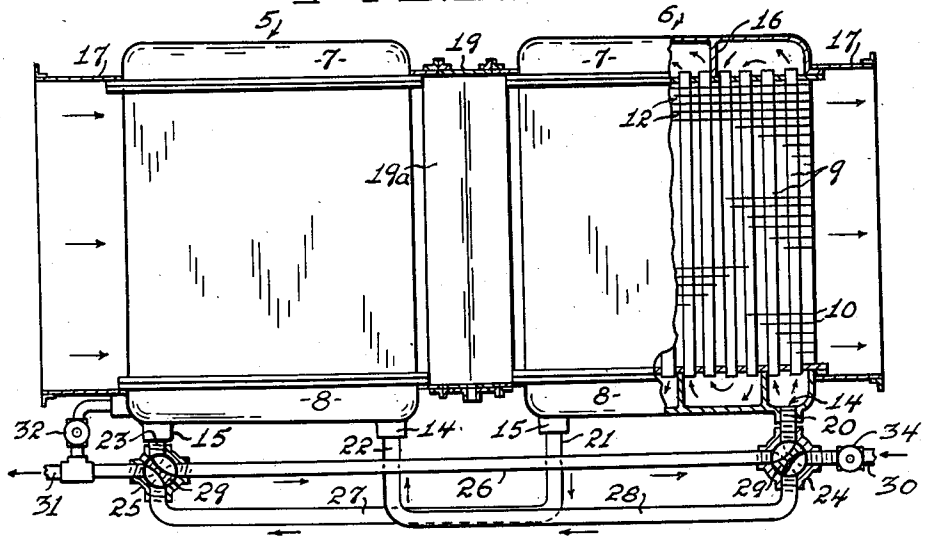


FIG. 1.

FIG. 2.



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AIR CONDITIONING SYSTEM WITH DEHUMIDIFIER AND REHEATER

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8 Claims. (Cl. 257—9)

The present invention relates to air-conditioning, particularly to air-conditioning systems designed to provide human comfort by maintaining a suitably low dew-point in the interior while regulating the dry bulb temperature independently of the degree of dehumidification required.

The simplest form of dehumidifier is one in which air is merely cooled, the degree of moisture taken from the air being a secondary consideration, whereas if such dehumidifier is a highly efficient heat transfer unit capable of producing a low final air temperature, the interior is frequently and wastefully over-cooled. Again, if such type of dehumidifier is caused to vary its final air temperature, no control is had over the dew point of the interior.

It is an object of this invention to provide for carrying out cooling-dehumidification-reheating in a simple manner and in a simple device, without the use of external heat and whereby the total refrigeration effect is only the latent heat of the moisture removed and the heat corresponding to the difference between initial air temperature before dehumidifying, and, the final air temperature after reheating.

It is another and important object of the invention to provide a dehumidifier which at all times, when supplied with water of a given degree, will, without the use of hygrostats, saturated air thermostats, and the like, deliver air at a dew point which varies only a negligible amount throughout the season.

Still another object of the invention is the provision of a dehumidifier-reheater unit which can be quickly converted to a highly efficient air heater by the supply of a hot circulated liquid, in place of the normally cold liquid.

It is an object of this invention to provide for cooling and reheating air for proper dry-bulb and dew-point control without the use of by-pass dampers, without by-passing, and with necessity for moving no more air than the air which actually goes through the dehumidifier.

Obviously, since for human comfort, lowering of the interior dew point is more important than lowering of the dry bulb temperature, it is apparent that where the air is dehumidified and then reheated, an interior can be treated with small amounts of well dehumidified air and the air-conditioning unit may be of greatly reduced frontal area as compared to the frontal area of a dehumidifier, which at times is required to pass relatively great quantities of air. Such reduced frontal area is another object of the invention.

In carrying out my invention the supply of air through the dehumidifier is constant; the air is cooled to a relatively low temperature, which for any interior establishes the dew-point of the interior; and is then reheated as required.

It is the primary object of this invention that the air so reheated, shall be reheated by extracting from it refrigerating effect which then is conserved for reuse.

In carrying out the present invention in the preferred embodiment to be described herein, I employ a counter-current air-cooler and dehumidifier of the type in which water or other cooling liquid enters at one end and flows forwardly while air enters at the other and flows rearwardly. Heat transfer surface separates the water from the air. The amount of water moved and amount of air moved are initially carefully regulated so that while the water cools the air close to initial water temperature the water is thereby heated to a temperature closely corresponding to the initial temperature of the air. Suitable means are provided for eliminating the condensation. If the dehumidifying requirements are slight then the amount of water and air moved are in the proportion of about one pound of water to each four pounds of air. Where the dehumidification is relatively great; that is where the major part of the heat to be extracted to cool the air is latent heat of water vapor, then the amount of water is increased but the maximum need not be more than three pounds of water per four pounds of air. In this way, air being cooled is caused to heat the water as highly as possible while the air being cooled is cooled as required without necessity for the initial water temperature being appreciably below the dew point required. This is particularly advantageous where the water is cooled by a refrigerating machine as it permits of running a comparatively high evaporator temperature with corresponding economy.

From the dehumidifier the air is moved on to a reheater. This reheater, according to this invention, may be identical in all arrangement of parts with the dehumidifier. Here the water, which has been heated in the dehumidifier to a degree corresponding to the degree to which the air has been refrigerated, acts to heat the air upwardly toward a temperature close to the temperature at which the water leaves the dehumidifier, and therefore reasonably close to the initial temperature of the air before dehumidification. In this way the water is again refrigerated and the difference in total heat of the water first entering the dehumidifier and the temperature

at which it finally leaves the reheater, is equal only to the net refrigeration effect imparted to the air.

In other words, the water is heated in first cooling the air and is then partially recooled in reheating the air. While in good practice the air should invariably be cooled, and is by the present embodiment cooled, to a constant dew-point, the degree of reheating is controlled easily by controlling the amount of water which passes through the reheater. Means are provided in the present embodiment for varying the relationship of the amount of water passed through the dehumidifier and the amount of water passed through the reheater, respectively.

The dehumidifier and the reheater, each identical in design and each capable of exchange of function with the other, are arranged in series. While in the dehumidifying reheating method water enters the rear of the dehumidifier, flows to the forward end thereof and then passes to the rear of the reheater, means are provided whereby the movement of valves will change the water flow so that both units are put in tandem, in which case the two units in tandem can be used for a common counter-current interchanger for cooling and/or heating in the usual manner.

The present embodiment is further capable of being operated with either of the two heat transfer units being used alone or in other various combinations as will appear hereinafter.

In the accompanying drawing I have shown said embodiment, and in the drawing:

Figure 1 is a diagram showing the arrangement of parts in said embodiment.

Figure 2 is a view on side elevation thereof; parts being shown in vertical section.

More specifically the numeral 5 indicates the dehumidifier and the numeral 6 the reheater. Each of these are identical in construction and accordingly a description of the construction and arrangement of parts of one will suffice for both. Each unit comprises opposed headers 7 and 8 respectively, a great multiplicity of tubes 9 passing from one header to the other, and fins 10 suitably arranged upon the outer surfaces of the tubes. Thus the tubes provide the water or liquid passages 11 while the fins provided a great multiplicity of air passages 12. This construction is common to heat transfer practice except that in this instance the water inlet opening 14 is at the end of one header and the water outlet opening 15 is at the other end of the same header, while baffles 16 divide the interior of the respective headers into a plurality of return-band passages. Thus water entering at 14 flows first through a few tubes only, then into the opposite header, then back through another few tubes, and so on, progressing toward the opposite end. This is known as counter-current interchange, when the air is moved as indicated by the arrows, in a direction opposite to the general progression of the water or liquid through the interchanger. Each such unit is enclosed in a housing 17 and when two such units are connected as shown the two housings form a continuous air passage for the air to be conditioned and air flows first through the forward unit and then through the rear unit. The complete assembly of the two units is supplied by a fan 18, which moves the air to be conditioned. An eliminator 19 is provided between the two units, this being of any well-known type capable of preventing free water from being passed on the reheater.

With the two units connected as shown, an inlet pipe 20 is provided for the inlet opening of the unit 6, and an outlet pipe 21 at the outlet opening of this unit. For the unit 5 an inlet pipe 22 is provided for the corresponding inlet opening, while at 23 an outlet pipe is provided for said unit at the outlet opening. Each unit is provided with a four-way valve of the well known type, the unit 6 having the valve 24 and the unit 5 the valve 25. The valve 24 of unit 6 is connected with the inlet pipe 20 and the valve 25 of unit 5 is connected with the outlet pipe 23 of unit 5.

The two valves, at points 90 degrees removed from the points at which they are each connected with the respective unit are joined by a cross-over pipe 26, so that with the valves in the position shown for example, the outlet of unit 5 is connected with the inlet of unit 6.

Diametrically opposite the point on the four-way valve 25, where it is connected with the outlet to unit 5, is connected a pipe 27 which leads to the outlet opening of unit 6. Likewise at valve 24 opposite where it connects with the inlet to unit 6, is a pipe 28 which leads to the inlet opening of unit 5.

The four-way valves are shown each provided with the usual vanes 29. The four-way valve is provided, at a point at right angle to where pipe 20 is connected and at a point opposite to where the cross over pipe 26 is connected, with a main supply line 30; which line is the main supply line for the complete air-conditioning unit. The corresponding pipe 31 at the valve 25, is the outlet for the entire air-conditioning unit as well as the individual outlet for the dehumidifier or unit 5.

Connected to pipe 23 and 31 respectively is a by-pass valve 32 which in open or partially open position will by-pass water around the valve 25 so that less water will be sent back through the unit 6 when the four way valves are as shown. A fan 18 is provided and connected to the duct or housing or unit 5 so that air from the fan is sent first through the unit 5 and then through unit 6.

In the form of the invention shown, operation in one instance is as follows: The fan 18 operates to send the air to be conditioned first through the unit 5 and then through unit 6. With the vanes of the valves in the positions shown, cold water enters pipe 30 and valve 24 and is thereby directed by the vane thereof to pipe 28 and through this to the inlet opening of unit 5. This water passes through unit 5 counter-flow to the air and cools the air down close to initial cold water temperature while the water is thereby heated to a temperature closely approximating initial air temperature. Now this water, so heated, leaves the outlet opening of unit 5, goes to valve 25, is directed by the vane thereof to and through pipe 26, goes to valve 24, is directed by the vane thereof to pipe 20 and thus into the rear end of unit 6 at the inlet opening thereof. Air from unit 5 passing counter-flow to the water coming from unit 5, and through unit 6, becomes heated, or reheated, back to a temperature only slightly below the temperature of the water leaving the unit 5. As this water moves forwardly in so heating or reheating the air, it is cooled and refrigerated to the same extent, in terms of heat units, that the water is reheated, so that it may truly be said that during reheating, refrigeration is regenerated. The net result

is that air leaves the unit 6 reheated well above dew point while the cost of reheating is nil.

To provide no reheating, as the case of a very excessive cooling load, the four-way valve 25 is moved to broken line position. In this position, water entering the dehumidifier first, leaves the system without going through the reheater, and therefore no reheating takes place and the unit 6 is thereby "cut out".

This use of the four-way valve is preferable only for total cut-off of the unit 6, and it will be noted that with valve 25 in broken line position and valve 24 as shown, this unit and corresponding system of pipes is entirely shut and not under pressure. However, the by-pass valve 32 is of course the real re-heating control as it limits the amount of heated water reaching the reheater and thereby limits the final temperature to which the air is reheated.

This valve may be manually or thermostatically controlled, and it is to be understood does not, in the method just described, have anything to do with dehumidifying, but as in a common heating system, controls the temperature to which the dehumidified air is heated.

At this point attention is called to the distinction between controlling final temperature of air by flow control of heating-water in a counter-current heater as compared with a single-pass heater. In the latter, reduced flow causes some of the air to be heated to a less degree than other parts. In the counter current method shown, when less water is supplied; all the air is heated but all to a lesser degree than if more water entered.

As far as the supply of cold water to the dehumidifier or unit 5 is concerned, it is to be understood that this is to be supplied at constant temperature for a constant dew point control. Using counter-current interchange, if too little water is supplied to dehumidifier it will be found that this water will be heated well but the air will not be cooled sufficiently close to initial water temperature. If too much water is used in this counter-current interchange method, then while the required dewpoint will be reached the water will not be sufficiently heated. Of course, variation of water supply by the initial supply valve 34 may be resorted to to control reheating to some degree, but for constant dew point results and close control over reheating, by-pass valve 32 is to be used.

Where the complete unit is employed for dehumidifying and cooling recirculated air or recirculated air with a small percent of new air, and where the dew point of the air or mixture is only a degree or so above required dew point, slightly more than one pound of water for each four pounds of air will suffice and will result in the water being heated in unit 5 close to room temperature, as the dry bulb temperature of the air or mixture will be closely approached by the water leaving the dehumidfier. In fact, where the atmospheric temperature is high and it raises the temperature of the mixture above room temperature, it may be possible to have the water leaving the dehumidifier heated to a temperature above room temperature.

When a very appreciable degree of dehumidifying is to take place it will be found necessary to use more water. This, for instance, will occur when the dehumidifier is handling new air only. If it is a humid climate where the dew point of the atmosphere is not far below the dry bulb, it will be found that as much as three-fourths of a pound of water, per pound of air, or three pounds of water per four pounds of air, will be required to reach the dew point with the same water temperature as is required for reaching the dew point when drier air is being handled.

Generally speaking, for a given general condition, the supply valve 32 is regulated to give the desired results, then by supplying the unit at all times with constant temperature cooled water the unit 5 will discharge air at the same dew point at all times.

It should be explained at this point that where air is not saturated, and at the usual atmospheric dew points encountered in air conditioning for human comfort, the total heat of air per degree above the dew point is approximately .24 while that of air below the dew point averages about .72 in average atmospheric conditions. If water is supplied to the dehumidifier along with dry air or air requiring only a very small amount of dehumidifying, I have found that one pound of water to four pounds of air will cause the water to heat through as high a temperature range as the air is cooled, and with an efficient interchanger the water will leave at a temperature close to initial dry bulb temperature of the air.

If, however, the air to be dehumidified is nearly saturated when it first enters the dehumifier, almost three pounds of water per each four pounds of air is required and the final water temperature will be not higher than initial wet bulb temperature.

If the dew-point of the atmosphere lies in the usual relation of appreciably below the dry bulb and still appreciably above the dew-point to which the air is to be dehumified, then the amount of water used is less than three pounds per four pounds of air. In this way I have found it possible when dehumifying atmospheric air, to have the heated water leave the dehumidifier at a temperature sufficiently above comfortable interior temperature that this water in the reheater will reheat the dehumidified air to a temperature equal to desired interior temperature so that no cooling effect is added to the interior.

This practice is sought after in many cases and obviously when some cooling effect is required it is only necessary to operate the valve 32 to reduce the amount of heated water fed to the reheater to thereby lower the final temperature to which air is reheated.

The four-way valves also permit of cutting out either unit in either heating or cooling practice. Thus if valve 25 is left as shown and valve 24 moved to broken line position, unit 6 functions and unit 5 is cut out.

With the valves in the position of broken line for both, the flow of water is first through the unit 6 and then through the unit 5. In heating practice this permits of a close interchange of heat as the both units become one of double length and increased total surface. If cold water is run through with the valves both in broken line position then the unit becomes an even more efficient dehumidifier.

Some conditions will permit of using both units in tandem for thorough dehumidifying, and then when the room begins to overcool, the aforesaid reheating method may be resorted to.

In fact, there are a great variety of combinations of valve settings, and initial water temperature conditions, to meet a wide variety of conditions, such as are known to those skilled in the art.

I claim:

1. In an air conditioning unit of the class de-

scribed, comprising, a counter-current-interchanger type of dehumidifier and a counter-current-interchanger type of reheater arranged to be successively encountered by air to be conditioned, means for moving a known quantity of air over said dehumidifier and interchanger, a cold liquid supply line connected with the rear of said dehumidifier, a heated-liquid return line connected with the forward end of said dehumidifier and leading to the rear end of said reheater, a cooler connected to supply cold liquid to said cold liquid supply line, and a return line leading from the forward end of said reheater back to said cooler.

2. In an air conditioning unit of the class described, comprising, a counter-current-interchanger type of dehumidifier and a counter-current-interchanger type of reheater arranged to be successively encountered by air to be conditioned, means for moving a known quantity of air over said dehumidifier and interchanger, a cold liquid supply line connected with the rear of said dehumidifier, a heated-liquid return line connected with the forward end of said dehumidifier and leading to the rear end of said reheater, a cooler connected to supply cold liquid to said cold liquid supply line, a return line leading from the forward end of said reheater to said cooler, and a valve for bleeding heated fluid from said heated-liquid return line back to said cooler.

3. In an air conditioning unit comprising, a counter-current-interchanger receiving air-to-be-conditioned at its forward end and discharging conditioned-air at the rear, a liquid supply line connected with the forward end thereof, means in said line for regulating the amount of liquid supplied to such extent that the total heat of the air to be conditioned and the total heat of the liquid are substantially equal, a reheating unit disposed to receive the conditioned air from said interchanger, and a liquid line connected to receive liquid from said interchanger and to convey liquid to said reheating unit, and a bleeder valve in said last named liquid line, and a liquid cooler connected to supply cold liquid to said liquid supply line and to receive liquid from said reheating unit.

4. The air-conditioning unit as in claim 1 and further including eliminators disposed between said dehumidifier and said reheater.

5. The herein described method for conditioning air having a dry bulb temperature higher than that required for human comfort and having a dew point higher than that required for human comfort, the method consisting in; passing cold water in counter-current heat-exchanging relationship to the air in such relative proportions as to cool the air to the dew point required for human comfort while thereby heating the water to a temperature above the dry bulb temperature required for human comfort, and then passing the so heated water in counter-current heat-transferring contact with the dehumidified air in such manner that the air is, or may be, heated to the aforesaid dry-bulb comfort temperature, while the water is accordingly re-cooled, and then further cooling the water to provide the aforesaid cold water.

6. In an air conditioning unit, a pair of successively arranged counter-current interchangers, each having respectively a fluid inlet and a fluid outlet, a liquid supply line, a fan for moving air over the units successively in counter-flow to the movement of liquid from the inlet of the last encountered interchanger toward the outlet of the first encountered interchanger, and movable liquid directing means in one position serving to direct liquid from the liquid supply line first to the inlet of the first encountered interchanger and thence from the outlet of the first encountered interchanger to the inlet of the last encountered interchanger; said means movable to a second position to then direct liquid, from the liquid supply line first to the inlet opening of the last encountered interchanger and thence from the outlet thereof to the inlet of the first encountered interchanger.

7. The air conditioning unit as in claim 6 and further including a bleeder valve at the outlet of the first encountered interchanger.

8. In a device of the class described, a pair of counter-current interchangers arranged to successively be encountered by passing air; each having an individual inlet opening and each having an individual outlet opening, a four way valve connected to the inlet opening of the last encountered interchanger, a second four-way valve connected to the outlet opening of the first encountered interchanger, a liquid supply line connecting with the first named four-way valve at a point at right angle to the point where the valve is connected to the inlet of the last encountered interchanger, a liquid outlet pipe connected to the second four-way valve at a point at right angle to the point where said valve connects with the outlet of the first encountered interchanger, a cross-over pipe connected at one end to the second four way valve at a point diametrically opposed to point where the outlet pipe is connected thereto; the cross-over pipe connected at the other end to the first named four-way valve at a point diametrically opposed to the point where the supply pipe is connected with said second fourway valve, a fourth pipe connecting the outlet opening of the last encountered interchanger with the second named four-way valve at the point diametrically opposed to the point where said second valve connects with the outlet of the first encountered interchanger, a fifth pipe connecting the inlet opening of the first encountered interchanger with the first named four-way valve at a point diametrically opposed to the point where said first named valve is connected with the inlet opening of the last encountered interchanger, a flow control valve on said supply pipe, and a by-pass valve disposed between the outlet opening of the first encountered interchanger and the aforesaid outlet pipe.

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