

"AIR CONDITIONING APPARATUS"

(2)

This invention relates to an air conditioning apparatus which establishes thermally comfortable conditions providing a pre-set combination of temperature and humidity.

5 The purpose of an air conditioning apparatus is to establish thermally comfortable conditions. In conventional air conditioning apparatus, control of comfortable conditions was attempted by controlling the temperature. In summer, for example, lowering of the
10 temperature was accomplished by a cooling device without any consideration of humidity. Accordingly, a relatively large temperature difference often exists between air-conditioned areas and non-air-conditioned areas. Such a temperature difference is not only unhealthy, but also
15 uncomfortable.

 To eliminate such problems, Japanese patent application no. 50-79691 to Matsushita Denki Sangyo K.K. teaches the use of a temperature sensor and a humidity sensor for generating electrical signals to energise a
20 cooling device, a dehumidifying device, or both, to establish and maintain thermally comfortable conditions from the well known fact that such conditions are established by properly controlling both temperature and the humidity.

25 The present invention seeks to provide an improved air conditioning apparatus which establishes thermally comfortable conditions by controlling flow of a refrigerant in order to automatically change from one operational mode to another, such as from a cooling mode
30 to a dehumidifying mode or vice-versa, according to the prevailing temperature and humidity.

According to the present invention there is provided an operational mode controller for an air-conditioning apparatus for controlling temperature and humidity comprising:

5 a temperature sensor arranged to produce a first signal substantially corresponding to said temperature;

 a humidity sensor arranged to produce a second signal substantially corresponding to said humidity;

10 means for combining said first signal and said second signal to produce a third signal substantially corresponding to the sum of said temperature signal and humidity signal;

 means for comparing said first signal, said
15 second signal and said third signal respectively with a given first signal substantially corresponding to a given temperature, a given second signal substantially corresponding to a given sum of said given temperature signal and said given humidity signal; and

20 an actuating means responsive to said comparing means for actuating said air conditioning apparatus to control the temperature when said temperature and said humidity exceed said given temperature and said given humidity while said sum
25 exceeds said given sum, to control the humidity when said humidity exceeds said given humidity while said temperature is below said given temperature and to stop controlling both the temperature and the humidity when both said temperature and said humidity are below said
30 given temperature and said given humidity while said sum is below said given sum.

One embodiment of the invention will now be described by way of example with reference to the accompanying drawings, in which:

35 FIGURE 1 shows a graph illustrating the operational zones as a cooler, a dehumidifier or a fan;

FIGURE 2 shows a refrigerant cycle of the air conditioning apparatus;

FIGURE 3 shows a wiring diagram for the air conditioning apparatus; and

5 FIGURE 4 shows an operational mode controller of the air conditioning apparatus.

The air conditioning apparatus of the present invention operates in one of three zones as shown in FIGURE 1 according to the prevailing temperature and
10 humidity. These zones are a cooling zone I, a dehumidifying zone II, and a "fan" or "comfortable" zone III. In cooling zone I, the apparatus operates in a cooling mode to lower the temperature. In dehumidifying zone II, the apparatus operates in a dehumidifying mode
15 to lower the humidity. In fan zone III, the apparatus operates only as a fan to circulate the air to maintain comfortable conditions.

A boundary line between cooling zone I and fan zone is called the "equal comfort" line 1. The equal
20 comfort line 1 is expressed by the following equation:

$$H + \gamma \cdot T = \beta \quad (1)$$

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where H is humidity, T is temperature, and γ and β are constants respectively.

10 The boundary line between cooling zone I and dehumidifying zone II is called the "cooling dehumidifying" line 2 which is expressed by the following equation:

$$T = T_0 \quad (2)$$

15 where T_0 is a fixed temperature.

The boundary line between dehumidifying zone II and fan zone III is called the "dehumidifying" control line 3 which is expressed by the following equation:

20 $H = H_0 \quad (3)$

where H_0 is a fixed humidity.

Accordingly, the intersection of the three lines 1, 2 and 3 has coordinates (T_0, H_0) .

25 If the apparatus starts operation at P in cooling zone I, it works as a cooler which lowers the temperature. As a cooler, it also lowers the humidity. The apparatus lowers the temperature and humidity until its operating point reaches the equal comfort line I as indicated at locus A of the operating points, shown in
30 FIGURE 1, if the humidity is kept below H_0 . When the operating point reaches line 1, the apparatus changes its mode from the cooling mode to the fan mode. The operating point may then go back into the cooling zone I because of
35 rise of temperature or humidity or both. Accordingly, the apparatus works along the equal comfort line 1 to maintain

comfortable conditions.

Locus A may intersect cooling-dehumidifying line 2 as shown by the dashed line in FIGURE 1, instead of line 1, depending upon the latent heat load. In such a case, the apparatus operates as a dehumidifier and it lowers the humidity to a predetermined level H_0 if the temperature is kept at T_0 .

Similarly, when the apparatus starts operation in dehumidifying zone II, it works as a dehumidifier which lowers the humidity to H_0 . When the operating point reaches line 3, the apparatus works as a fan to circulate the air.

The operating point of the apparatus is greatly dependent upon the latent heat load. However, the apparatus selects one of the operational modes automatically to establish or maintain thermally comfortable conditions.

FIGURE 2 shows a refrigerant circuit of the apparatus 50. A compressor 52 is provided to compress gaseous refrigerant to form liquid refrigerant. Compressor 52 pumps out the liquid refrigerant to a main condenser 54 connected to a capillary tube 56 functioning as an expansion device. A two-way electromagnetic valve 58 is connected in parallel with capillary tube 56. A sub-condenser 60 is connected to capillary tube 56 and electromagnetic valve 58. When electro-magnetic valve 58 is closed, the refrigerant flows into capillary tube 56 as indicated by a solid arrow B and its pressure is lowest thereat. Such expanded refrigerant can now evaporate at sub-condenser 60 and cool the air. On the other hand, when electromagnetic valve 58 is open, the refrigerant flows in electromagnetic valve 58 as indicated by arrow C and further flows in sub-condenser 60 without lowering its pressure as it passes through valve 58. Such refrigerant is further condensed to generate heat at sub-condenser 60.

Another capillary tube 62 is connected to sub-condenser 60, which functions as an expansion device for condensed refrigerant. A two-way electromagnetic valve 64 is connected in parallel with capillary tube 62, which is closed when electromagnetic valve 58 is open and vice-versa. An evaporator 66 is connected to capillary tube 62 and electromagnetic valve 64. Evaporator 66 cools the air, and the cooled air is warmed by heat generated at the condenser 60. Moisture is given up at the evaporator 66 and collected in a conventional manner and drained away. Thus, when the refrigerant flows in valve 58 so that the temperature remains unchanged, only the humidity is lowered. When the refrigerant flows in valve 64, air is cooled both at sub-condenser 60 and evaporator 66. Vaporised refrigerant then returns to compressor 52. A fan 67 is provided for circulating the air. A temperature-humidity controller or an operational mode controller 68 senses the temperature and the humidity and controls electro-magnetic valves 58 and 64 by a switch 70. Thus, apparatus 50 changes between the cooling mode and the dehumidifying mode by opening or closing electromagnetic valves 58 and 64.

FIGURE 3 is a wiring diagram of apparatus 50. A motor 72 of compressor 52 is energised by a power source 74 when a switch 76 is closed. Opening or closing of switch 76 is controlled by operational mode controller 68 which will be described in detail below with reference to FIGURE 4. When apparatus 50 operates in either cooling zone I and dehumidifying zone II, switch 76 is closed. Gate controllers 80 and 82 of electromagnetic valves 58 and 64 are selectively energised by switch 70 whose contacts (a-b) are normally closed so as to close valve 58 while another set of contacts (a-c) are normally open so as to open valve 64.

When switch 70 is energised, its contacts (a-b) are opened and contacts (a-c) closed. A motor 86 of fan 67 is normally energised by power source 74 through a normally closed switch 88.

5 FIGURE 4 shows operational mode controller 68 which includes a temperature sensor 90 and a humidity sensor 92. In temperature sensor 90, a negative temperature coefficient resistor 94 is provided. A d-c voltage V is divided by resistor 94 and a resistor 96.
10 Divided voltage V_1 is applied to a non-inverting input of an operational amplifier 98 through a resistor 100. A constant voltage V_2 is applied to an inverting unit of operational amplifier 98 through a resistor 102. A feedback resistor 104 is connected between the inverting
15 input and the output of operational amplifier 98. The output voltage V_3 of amplifier 98 is expressed as follows:

$$V_3 = V_1 + (V_1 - V_2) \cdot (R_{104}/R_{102}) \quad (4)$$

20 where R_{102} and R_{104} are values of resistors 102 and 104, respectively.

It will be understood from equation (4) that output voltage V_3 is proportional to input voltage
25 V_1 . Thus the detected temperature T can be expressed as follows:

$$V_3 = \gamma \cdot T \quad (5)$$

30 where γ is the constant used in equation (1).

The humidity is detected by humidity sensor 92 has a negative temperature coefficient resistor 106 whose impedance decreases when the humidity decreases. An alternating voltage produced by a device such as a
35 Wien bridge oscillator 108 is divided by resistor 106 and a resistor 110. A divided voltage V_4 is applied

as an input voltage to an AC-DC converter 112.

Detected humidity H can also be expressed as follows:

$$V_5 = H \quad (6)$$

An adder 114 which has two input terminals carries out the following addition:

$$V_3 + V_5 = V_6 \quad (7)$$

A comparator 116 compares output voltage V_6 of adder 114 with a constant voltage V_7 which is set to the sum of $\cdot T_0$ and H_0 . From equation (1),
 15 sum of $y \cdot T_0$ and H_0 equals . If output voltage V_6 is less than constant voltage V_7 ($V_6 \leq V_7 = \beta$) no output is generated at comparator 116. On the other hand, if output voltage V_6 is greater than constant voltage V_7 ($V_6 > V_7$), an output voltage V_8 is
 20 generated and is applied to one of input terminals of an OR circuit 118. An output terminal of OR circuit 118 is connected to a transistor 120 through a resistor 122. OR circuit 118 generates an output to turn on transistor 120 for energising a relay 122 to close switch 76.

25 Output voltage V_3 is applied to a comparator 124 and is compared with a constant voltage V_9 which is set at $\cdot T_0$. Comparator 124 generates an output voltage V_{11} when output voltage V_3 is less than constant voltage V_9 ($V_3 \leq V_9$). Output voltage
 30 V_5 is also compared at a comparator 126 with a constant voltage V_{10} which is set at H_0 . Comparator 126 generates an output voltage V_{12} when output voltage V_5 is greater than constant voltage V_{10} ($V_5 \geq V_{10}$).

Both output terminals of comparators 124 and 126 are connected to an AND circuit 130 whose output terminal is connected to the other input terminal of OR circuit 118 and to a transistor 132 through a buffer amplifier 134 and a resistor 136. When AND circuit 130 receives two inputs at the same time, it generates an output voltage V_{13} which turns on transistors 120 and 132 to energise the relay 122 to close switch 76 and a relay 138 to close contacts (a-c) of switch 70.

Accordingly, operations of compressor 52, electromagnetic valves 58 and 64 and fan 67 of the air conditioning apparatus 50 under various combinations of the temperature and humidity are shown by the table below

As set forth therein, the air conditioning apparatus of the present invention selects the operational mode automatically according to the temperature and humidity to operate as a cooler, a dehumidifier or a fan by controlling the flow of the refrigerant, and it prevents excessive cooling and establishes and maintains the thermally comfortable conditions defined by pre-determined combinations of temperature and the humidity. As the thermally comfortable conditions are obtained by controlling both the temperature and the humidity, the compressor of the air conditioning apparatus of the present invention has to work only intermittently rather than continuously, which contributes to saving of energy.

TABLE

Zone	Temperature Humidity	Compressor 52	Fan 68	Valve 58	Valve 64	Mode
I	T ≥ T. H ≥ H. or H < H.	ON	ON	CLOSED	OPEN	COOLING
II	T < T. H ≥ H.	ON	ON	OPEN	CLOSED	DEHUMIDIFYING
III	T ≥ T. or T < T. T < H.	OFF	ON	CLOSED	OPEN	BLOWING



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CLAIMS:

1. An operational mode controller for an
5 air-conditioning apparatus for controlling temperature and humidity comprising:
 - a temperature sensor arranged to produce a first signal substantially corresponding to said temperature;
 - 10 a humidity sensor arranged to produce a second signal substantially corresponding to said humidity;
 - means for combining said first signal and said second signal to produce a third signal
15 substantially corresponding to the sum of said temperature signal and humidity signal;
 - means for comparing said first signal, said second signal and said third signal respectively with a given first signal substantially corresponding to a given temperature, a given second signal substantially
20 corresponding to a given humidity and a given third signal substantially corresponding to a given sum of said given temperature signal and said given humidity signal; and
 - 25 an actuating means responsive to said comparing means for actuating said air conditioning apparatus to control the temperature when said temperature and said humidity exceed said given temperature and said given humidity while said sum exceeds said given sum, to control the humidity when
30 said humidity exceeds said given humidity while said temperature is below said given temperature and to stop controlling both the temperature and the humidity when both said temperature and said humidity are below
35 said given temperature and said given humidity while said sum is below said given sum.



2. An operational mode controller for an air-conditioning apparatus for controlling temperature and humidity as claimed in claim 1, wherein said comparing means includes:

a first comparator for comparing said first signal with a given first signal to produce a first output signal when said first signal is below said given first signal;

a second comparator for comparing said second signal with a given second signal to produce a second output signal when said second signal exceeds said given second signal; and

a third comparator for comparing said sum with said given sum to produce a third output signal when said sum exceeds said given sum.

3. An operational mode controller for an air-conditioning apparatus for controlling the temperature and humidity as claimed in claim 2 wherein said actuating means includes:

an AND circuit for producing a fourth output signal when both said first output signal and said second output signal are received; and

an OR circuit for producing a fifth output signal when either said third output signal or said fourth output signal is received.

4. An air-conditioning apparatus comprising:

a compressor for compressing the refrigerant;

a first condenser connected to said compressor for condensing refrigerant;

a first expansion device connected to said first condenser,

a first valve means connected in parallel with said expansion device;

a second condenser connected to said expansion device for further condensing the refrigerant when said



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first valve means is opened and for evaporating the refrigerant when said first valve means is closed;

a second valve means connected to said second condenser;

5 a second expansion device connected in parallel with said second valve means;

an evaporator connected to said second expansion device for evaporating the refrigerant; and

control means according to claim 1 for
10 alternatively opening or closing each of said first valve means and said second valve means; whereby said first valve means is closed and said second valve means is opened when a temperature and a humidity exceed a given temperature and a given humidity,
15 respectively, and a value substantially corresponding to a sum of said temperature and said humidity exceeds a given value substantially corresponding to a given sum of said given temperature and said given humidity;

20 and said first valve means is opened and second valve means is closed when said humidity exceeds said given humidity while said temperature is below said given temperature.

25 5. An air-conditioning apparatus as claimed in claim 4, further comprising:

means for de-energising said compressor when said temperature and said humidity are below said given temperature and said given humidity.

30 6. Air-conditioning apparatus substantially as herein described with reference to the accompanying drawings.