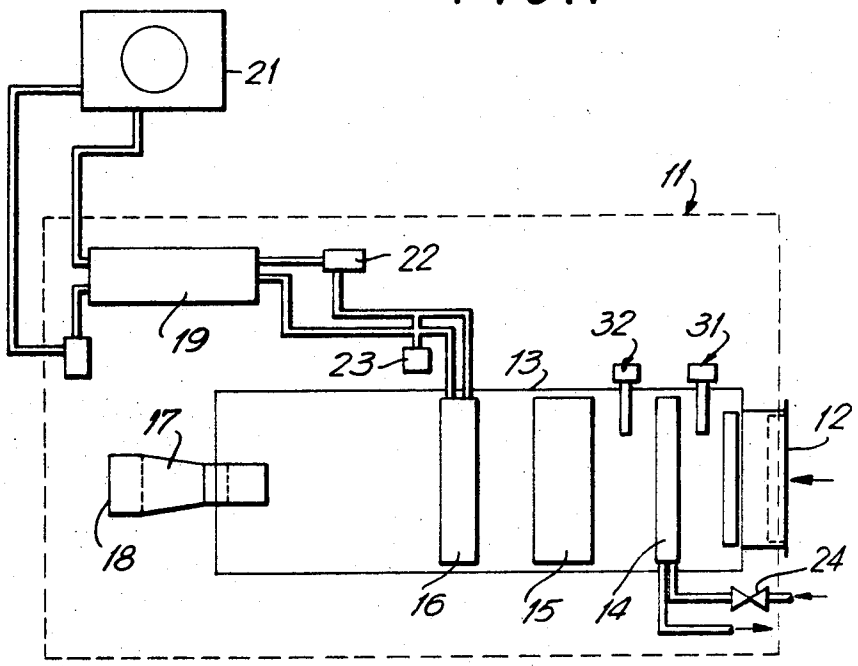
Sept. 24, 1968 T. COHEN 3,402,760

AIR-CONDITIONING SYSTEM HAVING FRESH AIR INTAKE

Filed Sept. 8, 1967 3 Sheets-Sheet 1

FIG. 1



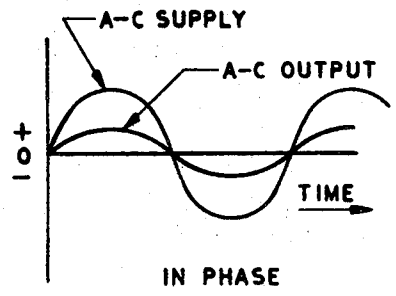


FIG. 3a

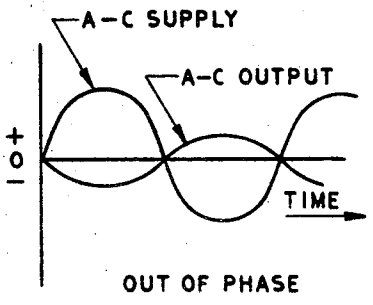


FIG. 3b

INVENTOR.
THEODORE COHEN

BY
Arthur B Cohen
ATTORNEY

Sept. 24, 1968 T. COHEN 3,402,760

AIR-CONDITIONING SYSTEM HAVING FRESH AIR INTAKE

Filed Sept. 8, 1967 3 Sheets-Sheet 2

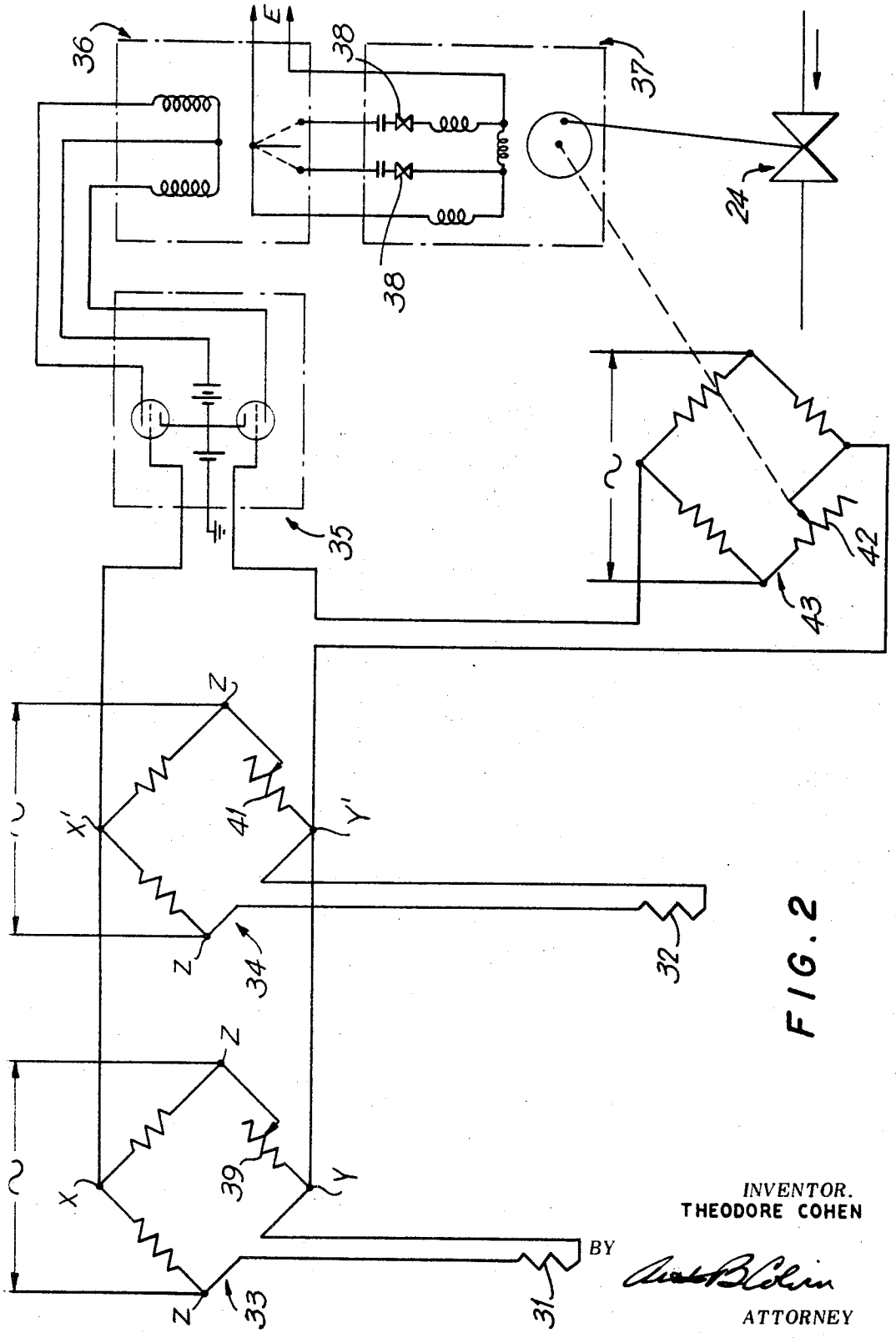


FIG. 2

INVENTOR.
THEODORE COHEN

BY

ATTORNEY

Sept. 24, 1968 T. COHEN 3,402,760

AIR-CONDITIONING SYSTEM HAVING FRESH AIR INTAKE

Filed Sept. 8, 1967 3 Sheets-Sheet 3

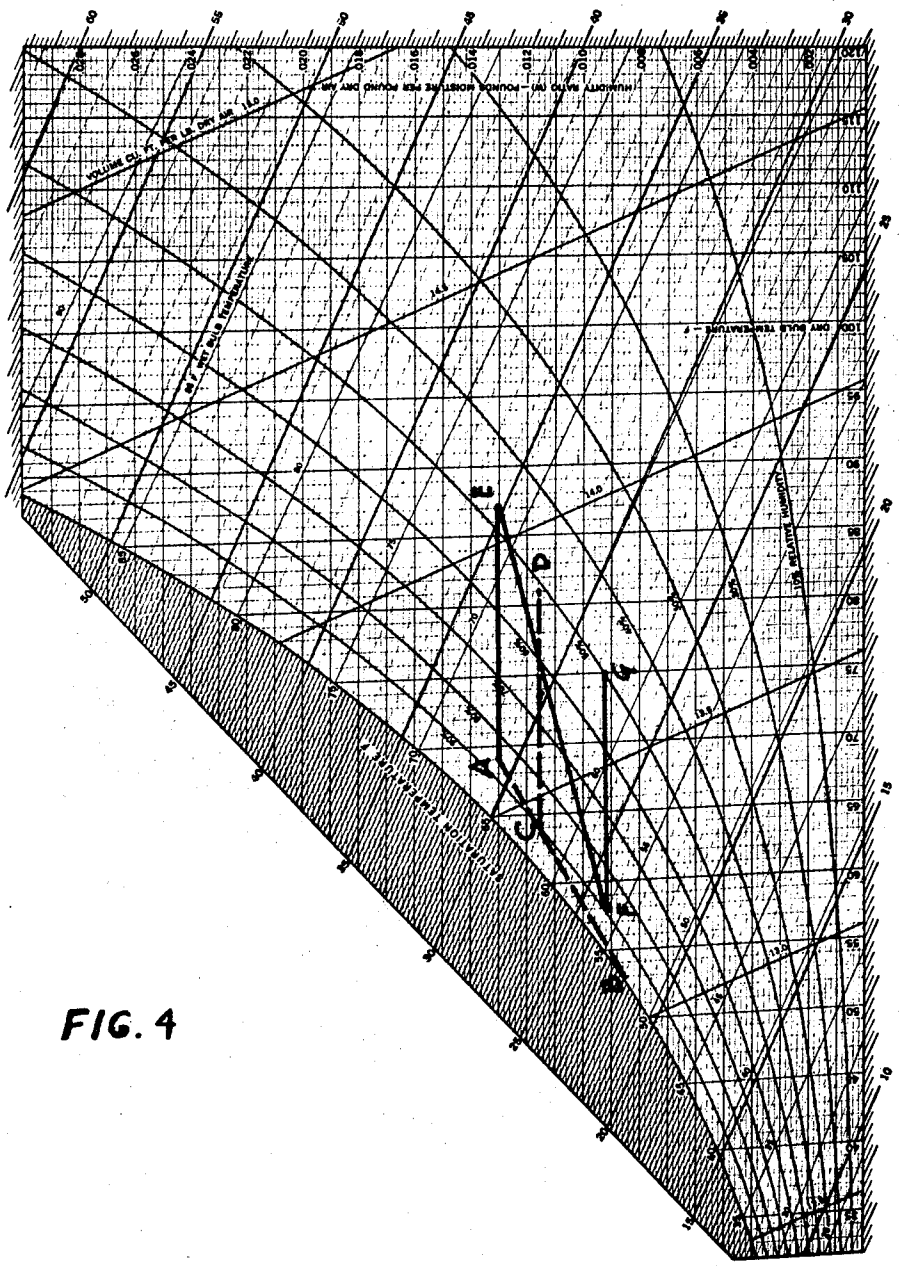


FIG. 4

INVENTOR
THEODORE COHEN

BY Arthur B Cohen
ATTORNEY

United States Patent Office 3,402,760
Patented Sept. 24, 1968

3,402,760

AIR-CONDITIONING SYSTEM HAVING FRESH AIR INTAKE

Theodore Cohen, 55 Ruxton Road,
Great Neck, N.Y. 11023

Continuation-in-part of application Ser. No. 485,325, Sept. 7, 1965. This application Sept. 8, 1967, Ser. No. 666,246
5 Claims. (Cl. 165—21)

ABSTRACT OF THE DISCLOSURE

An air-conditioning system of the type having a fresh air intake and a blower to draw air through said intake and discharge the same after it has been conditioned. Cooling means are located between the intake and the blower and heating means between the intake and the cooling means. Sensing means controlled by the humidity of the air entering the fresh air intake vary the temperature of the heating means correspondingly to vary the temperature of the air passing through the heating means before flow of such air through the cooling means.

This application is a continuation-in-part of copending application Ser. No. 485,325, filed Sept. 7, 1965, and now Patent No. 3,346,040.

As conducive to an understanding of the invention, it is noted that in many applications using air conditioning systems, it is essential that the outside or ambient air be drawn into the system and cooled for circulation into the room or other area to be cooled and the cooled air discharged to the outside after it has passed through the room to be cooled.

This is especially true in such places as operating rooms in hospitals where gases used during operations must be eliminated and hence there must be a constant fresh air intake and cooled air discharge to the outside. There are, of course, many other applications such as in industrial plants where fresh air intake is essential.

However, numerous problems exist when fresh air must constantly be cooled.

Thus, it is to be noted that the dry bulb temperature and the relative humidity of the fresh air entering an air-conditioning system varies over a wide range during the course of a summer season and even during the course of any one day.

Some systems, especially in the eastern region of the United States, are designed for fresh air entering the system at 95 ° F. dry bulb and 75 ° F. wet bulb which is equivalent to 95° F. wet bulb and 40% relative humidity. However, the range of conditions that actually occurs varies widely from this optimum and in different situations the following typical measurements have been made by the United States Weather Bureau.

Dry bulb temperature, degrees:	Relative humidity, percent
66	97
85	48
69	90
90	58

Generally speaking, the cooling coils of the most efficient air-conditioning units can only provide a 90% relative humidity, that is, the air immediately after it leaves the coils is at 90% relative humidity and say 58 ° F. dry bulb temperature. Where it is desired to have the room area at say 75 ° F. and 50% relative humidity, it is apparent that the air as it is discharged from the cooling coils must warm up from such lower temperature of say, 58 ° F. dry bulb.

Consequently, where the original humidity of the fresh air is high and the temperature is relatively low, the temperature of the air in the room to be cooled cannot be brought down to the desired value while at the same time bringing the humidity down to a comfortable level.

It is accordingly among the objects of the invention to provide an air-conditioning system of substantially conventional type which is designed to continually draw fresh air into the system and which incorporates control mechanism that may readily be installed with minor modifications in the standard equipment and which will permit the temperature and humidity in the room to be conditioned, to be within predetermined and desired limits regardless of the temperature and relative humidity of the fresh air brought into the system.

According to the invention, these objects are accomplished by the arrangement and combination of elements hereinafter described and more particularly recited in the claims.

In the accompanying drawings in which is shown one of various possible embodiments of the several features of the invention.

FIG. 1 is a diagrammatic view of an air-conditioning system,

FIG. 2 is a diagrammatic view illustrating the connection of the control devices of the present invention,

FIGS. 3*a* and 3*b* are diagrammatic views illustrating the operation of the system, and

FIG. 4 is a chart illustrating in broken lines the operation of a conventional air-conditioning system, and in solid lines the operation of the air-conditioning system according to the present invention.

Referring now to the drawings, as shown in FIG. 1, the air-conditioning system includes an air-conditioning unit **11** of substantially conventional type having a fresh air intake **12** connected by suitable conduits (not shown) to a source of fresh air.

The fresh air entering the intake **12** is drawn through a chamber **13** and then passes through the preheating coils **14**, a dust filter **15** and cooling coils **16**.

The cooled air is then drawn through a blower **17** to be discharged through supply ducts (not shown) from the outlet **18** of the blower **17**.

The cooling coils **16** are cooled in a conventional manner by means of suitable refrigeration equipment **19** in conjunction with the ancillary equipment such as a water cooling tower **21**, water pumps **22** and **23** and the like.

As the cooling coils may be cooled in any suitable manner and the particular means for cooling such coils is not per se part of the invention, it will not be described further.

The preheat coils also may be of any suitable type and in the illustrative embodiment, they may be heated by a source of steam, or hot water connected to valve **24**.

According to the invention, as shown diagrammatically in FIGS. 1 and 2, a humidity sensing element **31** is positioned in the fresh air intake between the intake **12** and the preheat coils **14**. In the embodiment herein shown an electronic humidistat of the type put out by the Honeywell Corporation under Model No. H7000A is preferred.

In addition, there is positioned between the preheat coils **14** and the filter **15**, a temperature sensing element **32** which senses the dry bulb temperature of the air after it passes the preheat coils **14**.

The temperature sensing device element also is of conventional electronic type such as that put out by the Honeywell Corporation under Model No. L–7022A.

The humidity sensing element **31** and the temperature sensing element **32** are each connected as one arm of separate balancing circuits such as Wheatstone bridges **33, 34**. The humidity bridge **33** and the temperature bridge **34** are conventional electronic components and are manufactured by Barber Colman Company as part No. CN 5301.

The combined output voltage of the two Wheatstone bridges **33** and **34** is amplified sufficiently by amplifier **35** to operate a single pole double throw relay **36** which in turn controls an electric motor **37**. In this case the amplifier **35** and the relay **36** are of the conventional type such as put out by the Barber Colman Company as proportional amplifier, part No. CP 5201.

The control valve **24** is actuated by electric motor **37**. This motor is operated in either a clockwise or counterclockwise direction by the relay **36**, to open or close the control valve **24**. The motor is equipped with cam operated limit switches **38** to stop the motor at the clockwise or counterclockwise ends of the travel. This is a standard motor operator of the type manufactured by the Barber Colman Company as "Motor Operator" MP 381.

As shown in FIG. 2, the humidity sensing element **31** forms one arm of the Wheatstone bridge **33**. The sensing element is a coil of wire with a chemical coating. The resistance value changes as the relative humidity of the air entering the air-conditioning system **12** rises or drops below the set point of the bridge determined by resistor **39** which forms a second arm of bridge **33**. As the resistance of the sensing element changes, the balance of the bridge **33** is upset and there is an output voltage across terminals X, Y of the bridge. This output voltage is applied to the terminals X', Y' of Wheatstone bridge **34** associated with the temperature sensing element **32**.

The temperature sensing element **32** forms one arm of Wheatstone bridge **34**. It comprises a coil of wire whose resistance changes as the temperature of the air leaving the preheat coil **14** rises or drops below the set point of the bridge determined by resistor **41** which forms a second arm of bridge **34**. As the resistance of the sensing element changes, the balance of the bridge is upset and there is an output voltage from the terminals X', Y' of the bridge.

The output voltage of the temperature sensing bridge **34** is thus added algebraically to the ouput voltage of the humidity sensing bridge **33** and the combined output voltage is applied to operate the control valve **24** based on the dry bulb temperature measured by the sensing element **32** as well as the relative humidity measured by the sensing element **31**.

Thus, the control valve **24** will be actuated an amount which is related to the relative humidity of the air entering the fresh air intake and the temperature of the air after it passes the preheat coils **14**.

As a result of the setting of the control valve **24**, the steam supply, for example, to the preheat coils **14** will be varied to increase or decrease the temperature of the preheat coils **14**.

In the operation of the air-conditioning system, it is turned on in conventional manner and the fresh air will be drawn through the intake **12** and pass through the cooling coils **16** so that the air is cooled for discharge by the blower **17** into the chambers to be cooled.

In conventional air-conditioning systems which for example, are designed to operate with fresh air entering the system at a maximum of 95° F. dry bulb and 40% relative humidity, if in fact the air enters the system at 69° F. dry bulb and 85% relative humidity, referring to the chart, FIG. 4, where A indicates the condition of the air entering the system, if the room to be cooled is to be maintained at a temperature of 75° F. dry bulb and a humidity of 50%, the conventional system will not achieve such results.

Thus, the design of all cooling coils is such that referring to the chart, FIG. 4, the most effective conditioning process line that can be obtained is a line tangent to the saturation line (100% relative humidity). This is the most efficient process that any cooling coil can produce. Thus, such line will extend from A to B (tangent to the saturation line).

Since practically the most efficient air conditioners provide 90% relative humidity to the air as it leaves the

cooling coils, the dry bulb temperature of such air in the line A–B will be at C and equal to 64° F. dry bulb.

Thus, the air supplied to the space to be cooled will have a humidity of 90% and a dry bulb temperature of 64° F. when it leaves the cooling coils **16**.

The internal load of the air-conditioned space, in the illustrative example herein, will heat the conditioned air 17° F., so that the room temperature will be at point D, i.e., 81° F. dry bulb and 52% relative humidity.

Thus, the temperature and humidity would be in excess of that required for comfort, i.e., 75° F. dry bulb and 50% relative humidity.

According to the invention herein, the air entering the system will be at point A on the chart, FIG. 4, i.e., it will have a dry bulb temperature of 69° F. and 85% relative humidity.

The control point of the humidity sensing device **33** is set for 40% relative humidity. The control point of the temperature sensing device **34** is set for 60° F. In this case, since both the entering relative humidity (85%) and the entering temperature (69° F.) are different from the control points of the sensing instruments, the balance of each respective Wheatstone bridge will be upset and each will have a voltage output.

The control points that have been selected are not completely arbitrary (40% R.H. and 60° F. respectively). At relative humidities below 40% R.H. there is no combination of outside air temperature and relative humidity that cannot be handled by the air-conditioning system. All of the problems occur at higher relative humidities.

With regard to the temperature sensing element, at entering air temperatures below 60° F., the air conditioning system does not encounter any problems. The entering air is usually preheated to 60° F. This is considered a minimum entering temperature.

Most modern power circuits are supplied with alternating current and for this reason alternating current Wheatstone bridges are used in this control system.

When the bridges are energized as at Z, by an A.C. supply voltage, an A.C. output voltage results. Instead of becoming plus or minus as in the case of D.C. bridge circuits, the output changes its phase relationship with respect to the supply voltage. The phase relationship between two voltages or currents is determined by the alignments of the peaks, valleys, and null points as shown in FIGS. 3*a* and 3*b*.

When the corresponding points on the curves are in line, the two quantities are said to be in phase, FIG. 3*a*. In FIG. 3*b* the voltages are out of phase, in this case by 180° of angular displacement.

In this case, the net output voltage of the two Wheatstone bridges is the sum of the two individual bridge outputs if they are both in phase with the A.C. supply voltage. If the two individual bridge voltage outputs are out of phase the net output voltage is the difference between the two output voltages.

The following tables illustrate a typical schedule of voltage outputs from the relative humidity and temperature bridges for the range of temperature and relative humidity that we are concerned with.

Relative humidity bridge, percent relative humidity	Output voltage (millivolts)	
0	6.68	This voltage output is in phase with the A. C. supply voltage.
10	5.01	
20	3.34	
30	1.67	
[1] 40	0	This output voltage is out of phase with the A.C. supply voltage.
50	2	
60	4	
70	6	
80	8	
90	10	

[1] Set point of humidity controller 31.

Temperature bridge, ° F.	Output voltage	
10	30	This output voltage is out of phase with the supply voltage.
40	6.67	
50	3.33	
[1] 60	0	
70	3.33	This output voltage is in phase with the A.C. supply voltage.
80	6.67	
90	10	

[1] Set point of temperature controller 31.

The output voltages from each bridge for the entering air conditions (69° F. and 85% R.H.) that is selected for the example are taken from the above tables by interpolation.

Humidity bridge: 85% R.H.=9.0 millivolts (mv.) (out of phase with the A.C. supply voltage)

Temperature bridge: 69° F.=3.0 mv. (in phase with the A.C. supply voltage)

The combined output voltages of both bridges is 9 mv.—3 mv.=6.0 mv. (out of phase with the A.C. supply voltage).

It is desirable for the motor **37** to position the control valve **24** so that the flow of steam will be proportional to the change at the sensing elements and therefore proportional to the combined voltage output of the temperature and humidity bridges. For example, at a voltage output of 0 mv., the control valve **24** will be closed. At a voltage output of 10 mv., the control valve **24** will be wide open.

For a given change in the output voltage of the combined bridges the motor **37** and the control valve **24** will move to a definite and corresponding position which is proportional to that increment.

Proportional action is accomplished through feedback which links the motor **37** to the combined Wheatstone bridges **33**, **34**. As the motor moves in response to a change in the voltage output of the bridges **33**, **34**, a resistor **42** in feedback bridge **43** is actuated. A signal builds up which is returned to the combined bridges. The feedback voltage is opposite to the voltage output of the Wheatstone bridges, and opposes the voltage output of the combined bridge. Thus balance is restored to the system when the motor reaches a position which is proportional to the voltage output of the Wheatstone bridges.

Referring to the table for the output voltages for the temperature bridge, an output voltage of 6.0 mv. (out of phase with the A.C. supply voltage) corresponds to an air temperature of 41.98° F. at the temperature sensing element **32**. In other words, for a simple electronic heating control system consisting of a temperature controller and temperature bridge, if the set point of the controller is 60° F. and the air temperature at the sensing element is 41.98° F., the output voltage of the Wheatstone bridge would be 6.0 mv. (out of phase with the A.C. supply voltage). To reestablish the balance of the temperature bridge (i.e., voltage output is 0 mv.) the motor operator **37** opens the control valve **24** which regulates the flow of steam to the preheat coils **14** so that the air temperature of the entering air is raised by 18.2° F., the difference between 60° F. and 41.98° F. The resulting air temperature will be 69° F.+18.02° F. or 87.02° F. This corresponds to point E on chart, FIG. 4, at which the humidity will be 47%.

In other words, the humidity sensing element **31** and the relative humidity bridge are used to reset the control point of the temperature bridge **34**. In this example the temperature and humidity bridges will be in balance when the entering air is heated from 69° F. to 87.02° F. which is the desired effect to overcome the problem caused by excessively high relative humidity in the entering air.

The preheated air will then pass through the cooling coils **16** and will be cooled to 58° F. and 90% relative humidity. This is indicated by the line E–F which is a practical process line available with modern air-conditioning equipment.

For the same internal load conditions as set forth above, i.e., a temperature rise of 170° F. in the room to be cooled, the process line will extend from point F to point G. The resulting space conditions at point G will thus be 75° F. and 50% relative humidity as desired.

As above described, the relative humidity device **33** acts as a master control to reset the control point of the temperature sensing device **34**. As the relative humidity of the ambient air increases, the control point of the temperature sensing device **34** is raised and as the relative humidity of the ambient air drops, the control point of the temperature sensing device is lowered.

Although, as herein described, the unit is electronically controlled, it is apparent that it can be electrically or pneumatically controlled.

As many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without the departing from the scope of the claims, it is intended that all matter contained in the above description, or shown in the accompanying drawings, shall be interpreted as illustrative and not in a limiting sense.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent of the United States is:

1. An air-conditioning system of the fresh air intake type comprising a fresh air intake, a blower to draw air through said intake and discharge the same after it has been conditioned, cooling means between the intake and the blower, heating means between the intake and the cooling means, sensing means to control said heating means thereby to vary the temperature of the air passing the heating unit before flow of such air through the cooling means, said sensing means comprising a humidity sensing device including a sensing element, a temperature sensing device including a sensing element, said temperature sensing element being positioned between said heating means and said cooling means, said humidity sensing device being controlled by variations in the relative humidity of the air entering the air intake, said humidity sensing device having a control outlet, said temperature sensing device having a control inlet connected to said control outlet and also having a control outlet controlling the temperature of said heating means, said humidity sensing device and temperature sensing device each comprises a balancing circuit, each balancing circuit having an adjustable control unit, said humidity sensing element and temperature sensing element are electrically connected in said humidity sensing device and temperature sensing device respectively, the control outlet of said humidity sensing device being connected to the control inlet of said temperature sensing device, and means to apply a source of alternating current potential to energize each of said sensing devices, whereby variations in the humidity sensed by said humidity sensing device will cause corresponding variations to be applied to the control inlet of the temperature sensing device to change the control point of said temperature sensing device for corresponding variations in the control outlet thereof to correspondingly change the temperature of the heating means.

2. An air-conditioning system of the fresh air intake type comprising a fresh air intake, a blower to draw air through said intake and discharge the same after it has been conditioned, cooling means between the intake and the blower, heating means between the intake and the cooling means, sensing means to control said heating means thereby to vary the temperature of the air passing the heating unit before flow of such air through the cooling means, said sensing means comprising a humidity sensing device including a sensing element, a temperature sensing device including a sensing element, said temperature sensing element being positioned between said heating means and said cooling means, said humidity

sensing device being controlled by variations in the relative humidity of the air entering the air intake, said humidity sensing device having a control outlet, said temperature sensing device having a control inlet connected to said control outlet and also having a control outlet controlling the temperature of said heating means, said humidity sensing device and temperature sensing device each comprises a Wheatsonte bridge balancing circuit, each balancing bridge having an adjustable control unit in one arm respectively, said humidity sensing element and temperature sensing element are electrically connected in an opposed arm of said humidity sensing bridge and temperature sensing bridge respectively, the control outlet of said humidity sensing bridge being connected to the control inlet of said temperature sensing bridge, and means to apply a source of alternating current potential to energize each of said bridges, an amplifier connected to the output of said temperature sensing bridge and means controlled by the output of said amplifier to control the temperature of the heating means, whereby variations in the humidity sensed by said humidity sensing device will cause corresponding variations to be applied to the control inlet of the temperature sensing device to change the control point of said temperature sensing device for corresponding variations in the control outlet thereof to correspondingly change the temperature of the heating means.

3. The combination set forth in claim **1** in which each of said balancing circuits comprises a Wheatstone bridge, each of said adjustable units forms one arm of an associated bridge and each of said sensing elements forms an opposed arm of each of said bridges.

4. The combination set forth in claim **2** in which said heating means comprises a coil through which heated fluid may flow, a valve controlling flow of such heated fluids through said coil, a reversible motor controlling said valve, a relay to control said motor, the output of said amplifier being connected to said relay to actuate the latter.

5. The combination set forth in claim **4** in which a balancing circuit is provided having a variable resistor controlled by the position of said motor, said balancing circuit having an output connected to the output of said temperature sensing device to provide feedback to the input of said amplifier.

References Cited

UNITED STATES PATENTS

1,984,135	12/1934	Houston	165—21
2,053,042	9/1936	Otto	165—21
2,195,781	4/1940	Newton	165—21 XR
2,913,902	11/1959	Ross.	
3,118,601	1/1964	Robb	236—44
3,346,040	10/1967	Cohen	165—21

ROBERT A. O'LEARY, *Primary Examiner.*

M. A. ANTONAKAS, *Assistant Examiner.*