United States Patent

Eckman et al.

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[45] **Aug. 8, 1972**

[54] **AIR CONDITIONING APPARATUS**

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[21] Appl. No.: **58,373**

[52] **U.S. Cl.** **236/38,** 236/49, 236/78

[51] **Int. Cl.** **F24f 11/04**

[58] **Field of Search** .....236/1 B, 38, 49, 78

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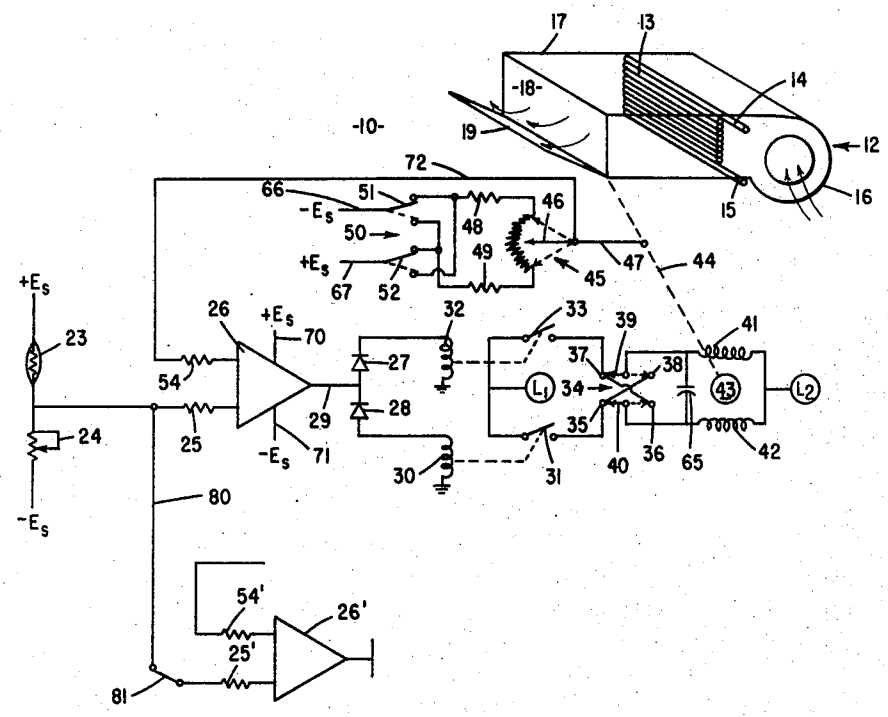
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[57] **ABSTRACT**

Apparatus for supplying treated air to an enclosure, including a heat exchanger to which a heat exchange medium flows and a fan arranged to route air to be treated over the heat exchanger in heat transfer relation with the medium. A structure serving as an air passage functions to supply treated air to one or more outlets. The discharge area of the outlets is modulated in response to changes in room temperature, while the speed of the fan remains substantially constant.

1 Claim, 2 Drawing Figures



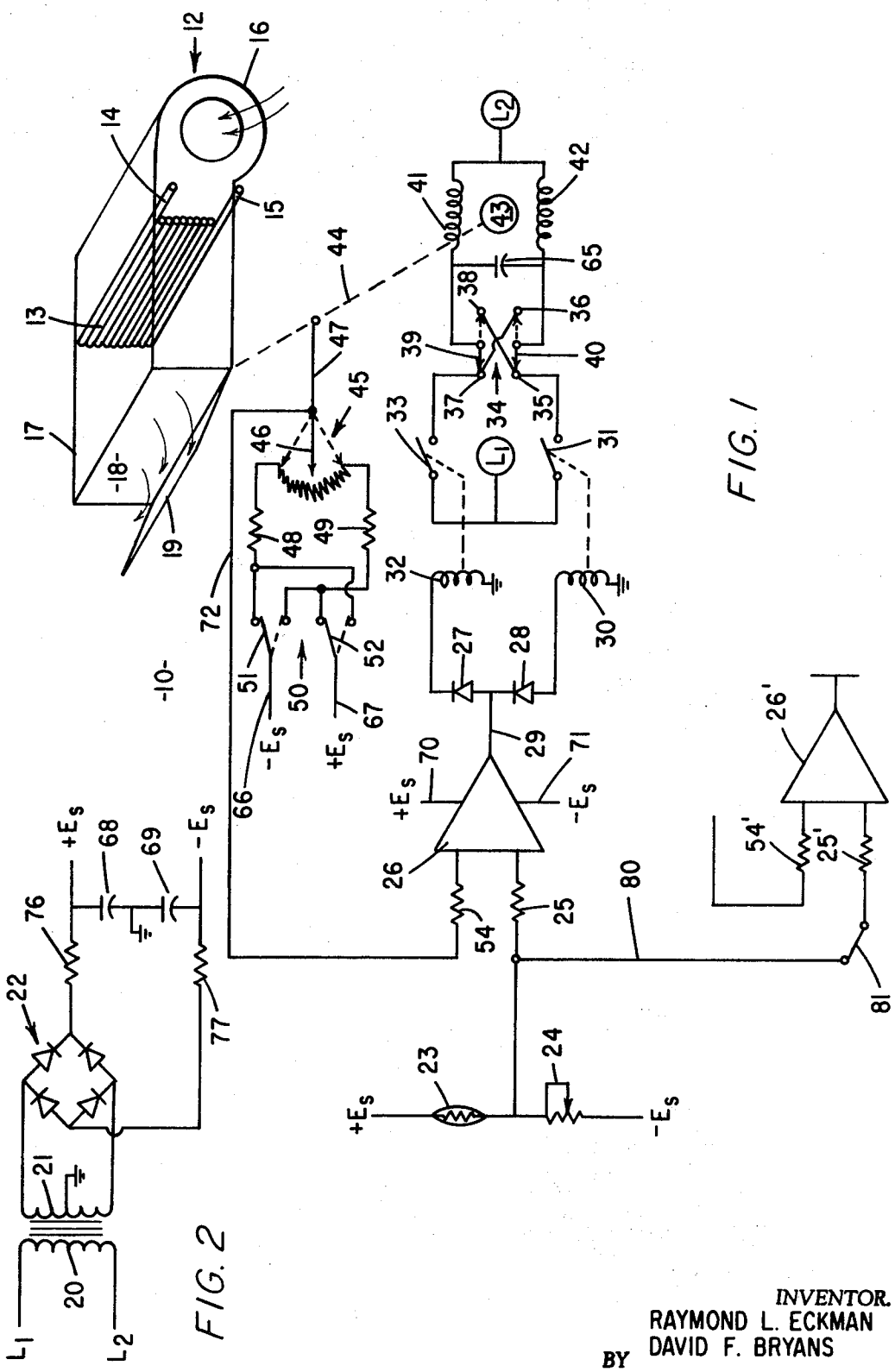


FIG. 1

FIG. 2

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AIR CONDITIONING APPARATUS

BACKGROUND OF THE INVENTION

This invention relates to an air conditioning apparatus and, more particularly, to an arrangement for controlling the discharge of treated air from said apparatus.

Air conditioning apparatus of the type employing a heat exchange coil to circulate a heat exchange medium therethrough, for example, chilled or warmed water, and having a fan for bringing air to be conditioned into heat transfer relation with the medium flowing through the coil are well known and widely employed by those skilled in the air conditioning art. Such apparatus are generally referred to as fan coil units.

Fan coil units are employed with central station cooling and heating machinery for conditioning multi-room buildings, such as motels, hotels, and apartments. Such apparatus afford a relatively effective means for simultaneously conditioning a plurality of areas in a common enclosure, while providing individual control by the occupants of each area. In addition, fan coil units are relatively simple to install and to maintain in operating condition and are relatively inexpensive, making such units particularly suitable for low-cost, multiple dwelling housing. However, some problems have been encountered which reduce the overall efficiency and effectiveness of their operation.

For example, on-off cycling of the typical fan coil unit creates annoying sound variances. In addition, an on-off type of control does not provide uniform air distribution. Particularly, temperature variations of a considerable magnitude above and below the room setpoint may be produced in portions of the room, the variations being caused by stratification of the air during the off cycle. Furthermore, it has been determined that a more efficient control of the humidity level, when the apparatus is operating on cooling mode, may be obtained by continuously operating the fan, rather than employing an on-off cycle of operating or modulating the cold water flow to the heat exchange coil.

It is an object of this invention to overcome the problems hereinabove noted by providing a novel air conditioning apparatus.

SUMMARY OF THE INVENTION

This invention relates to an air conditioning apparatus and, more particularly, to an improved arrangement for controlling the flow of treated air from such apparatus.

The apparatus includes a heat exchanger adapted to receive a heat exchange medium, such as chilled or warmed water, which may be treated in a central station or other remote location. A fan is operable to route air to be treated over said heat exchange coil in heat transfer relationship with the medium flowing therethrough. A temperature sensing element is installed in the area being treated, and is operable to generate a signal, the magnitude thereof being related to the sensed temperature in the treated area.

The treated air from the heat exchange medium is passed to one or more outlets of the apparatus by a structure serving as an air passage. Each outlet includes means operable to receive the control signal generated by the temperature sensing element and is further operable to modulate the position of the outlet as a function of a sensed temperature.

By varying the position of the outlet to regulate the discharge area through which the treated air passes into the enclosure, the quantity of treated air delivered to the enclosure is modulated to meet specific load requirements. The fan supplying the treated air may thus remain operational at all times, thus obviating the prior art difficulties.

In addition, by decreasing the discharge area of the outlet, as the requirement for treated air is diminished, the static pressure in the air passage is increased. As is well known, velocity is a function of static pressure. Thus, by increasing the static pressure, the velocity of the treated air discharged into the enclosure is increased. By increasing the velocity of the air discharged into the enclosure, the momentum of the air is maintained substantially constant, regardless of the reduction in the quantity of air being discharged. As conditions change, so that a greater quantity of treated air is required, the area of the outlet will increase. Although the static pressure and thus the velocity will be concurrently decreased, the momentum will remain substantially constant due to the increased supply of treated air.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic view of a fan coil unit of the type described equipped with a control circuit illustrating the invention; and

FIG. 2 is a schematic diagram illustrating the circuit used to convert conventional AC voltage to DC voltage to provide a source of power for the circuit illustrated in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawing, there is shown a preferred embodiment of an air conditioning apparatus including the invention disclosed herein.

Reference numeral **10** indicates an area in an enclosure which is to be treated by having air at a predetermined temperature discharged therein. Although it is within the scope of the invention to have only one such area or room being conditioned, it should be understood several rooms, each employing apparatus embodying the subject of this invention, may be conditioned simultaneously.

The illustrated embodiment includes an air conditioning apparatus **12**. Apparatus **12** includes a heat exchange coil **13** to which a heat exchange medium, such as cold or warm water, is supplied via conduit **14**. The heat exchange medium is supplied at a predetermined temperature which is regulated by central station refrigeration machinery (not shown). The heat exchange medium is returned to the central station machinery via conduit **15**. Fan **16** operatively connected to a motor routes ambient air over the heat exchange coil in heat transfer relation therewith. The ambient air is treated by passing in heat transfer relation with the heat exchange medium flowing through the coil.

The air conditioning apparatus **12** is mounted in a structure **17** which defines an air passage through which the treated air is supplied to at least one outlet **18** for delivery to the room or enclosure being treated. Damper **19** regulates the passage of air to the enclosure from outlet **18**. The manner in which damper **19** is con-

trolled in accordance with the invention disclosed herein shall be more fully explained hereinafter.

As noted hereinbefore, it is desirable to regulate the quantity of treated air being supplied to the enclosure in accordance with the load requirements thereof. By regulating the position of damper **19** to vary the discharge area from outlet **18**, it is possible to modulate the supply of treated air as is desired, while maintaining fan **16** continuously operative, thereby eliminating the prior art difficulties noted hereinbefore.

It should be understood that the speed of the fan is maintained to provide the necessary supply of treated air to meet the maximum load requirements for which the apparatus **12** is designed to handle.

Furthermore, the novel arrangement herein disclosed operates to maintain the momentum of the treated air discharged into the enclosure substantially constant by increasing the velocity of the air when the quantity thereof has been reduced; and similarly, decreasing the velocity of the air when the quantity of the air being discharged has been increased.

The control circuit provided for obtaining the desirable features hereinbefore described is merely illustrative, and other control schemes that might perform a similar function may be employed in lieu thereof.

The control circuit includes a voltage transformer operable to reduce the line voltage represented by lines L_1 and L_2 to a smaller voltage for control purposes. The voltage transformer includes a primary winding **20** and a secondary winding **21**. Preferably, the current flowing through lines L_1 and L_2 is 60 cycle alternating current. Since the control circuit, to be more fully explained herein, utilizes solid state components operable on direct current, a full wave diode rectifier circuit **22** is provided as a source of DC voltage, the DC voltage source being represented by $+E_s$ and $-E_s$. Resistors **76** and **77** and capacitors **68** and **69** are provided to filter the DC voltage.

Thermostat elements **23** and **24** are connected in series with the source of DC voltage. Element **24** is preferably a variable resistance element, such as a potentiometer, that may be selectively regulated by the occupant to obtain a desired temperature in the enclosure. Element **23** is preferably a NTC thermistor positioned to sense the temperature of the air in the enclosure. Elements **23** and **24** operate in combination to provide a variable voltage signal. When the temperature of the enclosure is above the setpoint established by thermal element **24**, the voltage signal is of a relatively large magnitude and of a positive polarity, whereas when the temperature is below the setpoint, the voltage signal is of a relatively large magnitude and of a negative polarity.

The voltage signal from elements **23** and **24** is supplied to a first input of operational amplifier **26**, through resistor **25**. The manner in which operational amplifier **26** functions shall be more fully explained hereinafter. Operational amplifier **26** also has supplied thereto a $+E_s$ voltage through line **70** and a $-E_s$ voltage through line **71**.

Connected to the output of the operational amplifier is a first diode **27** and a second diode **28**. Diode **28** permits only passage of a negative supply voltage, whereas diode **27** only permits passage of a positive voltage signal.

Connected in series with diode **27** is relay coil **32**, the energization thereof operating to close normally open switch **33**. Connected in series with diode **28** is relay coil **30**, the energization thereof operating to close normally open switch **31**.

Connected to the output from either switch **31** or switch **33** is double-pole, double throw switch **34**. Switch **34** includes a first arm **39** which selectively connects either terminal **37** or terminal **38** in the circuit. Terminal **37** is connected into the circuit when the apparatus is providing relatively cold air, whereas terminal **38** is connected in the circuit when the apparatus is providing relatively warm air. Switch **34** also includes arm **40** which selectively places either terminal **35** or terminal **36** into the circuit. Terminal **35** is placed in the circuit when the apparatus is providing relatively cold air, and terminal **36** is placed in the circuit when the apparatus is providing relatively warm air.

Switch **34** may be controlled manually or may be operated automatically by means such as a bimetal switch which would be placed in heat transfer relation with the heat exchange medium flowing to heat exchange coil **13**.

Connected in series with switch **34** are windings **41** and **42** of a reversible motor **43**, connected to the source of alternating current as represented by lines L_1 and L_2. The energization of winding **41**, prior to the energization of winding **42**, will actuate the motor so that the damper will rotate in a counterclockwise direction so that the discharge area of outlet **18** is increased.

Conversely, the energization of winding **42**, prior to the energization of winding **41**, will actuate motor **43** so that damper **19** will rotate in a clockwise direction to decrease the discharge area from outlet **18**. Motor **43** is operatively connected to damper **19** via shaft **44**. Capacitor **65** is included between windings **41** and **42** to establish the necessary phase displacement therebetween.

Operatively connected to shaft **44** is shaft **47**. Shaft **47** has movably connected thereto wiper **46** of potentiometer **45**. The rotation of shaft **44** so as to decrease the area of discharge outlet **18** will rotate wiper **46** in a clockwise direction, whereas rotation of shaft **44** so as to increase the area of discharge outlet **18** will rotate wiper **46** in a counterclockwise direction.

Connected in series with potentiometer **45** is a second double-pole, double throw switch **50**. Switch **50** includes arm **51** and arm **52**. As shown by the solid line, arms **51** and **52** are positioned for cooling mode operation. As shown by the dotted lines of the Figure, arms **51** and **52** are positioned for heating mode operation. The operation of switch **50** may be manually or automatically regulated.

Connected in series with switch **50** and potentiometer **45** are fixed resistors **48** and **49**. Lines **66** and **67** are connected to the source of rectified DC voltage so as to bring the supply voltage to potentiometer **45**.

Depending upon the mode of operation and the position of wiper **46** as controlled by the position of damper **19**, either a positive polarity or a negative polarity voltage signal, the signal being proportional to the position of the damper, will be supplied via line **72** and resistor **54** to a second input of operational amplifier **26**.

The operational amplifier compares the voltage signal regulated by potentiometer **45** to the voltage signal regulated by thermal elements **23** and **24**, to operate motor **43** so that the position of damper **19** is modulated in response to the temperature of the enclosure.

To better understand the manner in which the control circuit operates in accordance with the invention, assume that cooling mode operation is desired and that the temperature of the enclosure is above the setpoint.

The magnitude of the variable voltage control signal controlled by thermal elements **23** and **24** will be sufficient to cause operational amplifier **26** to pass a positive polarity voltage signal from line **70** to line **29**.

The $+E_s$ voltage signal will pass through diode **27** and energize coil **32**, thereby closing switch **33**.

When switch **33** closes, line voltage represented by L_1 and L_2 will pass through arm **39** of double-pole, double throw switch **34** which is in contact with terminal **37**, thereby energizing coil **41** of motor **43**. The motor will thus be actuated to turn shaft **44** in a counterclockwise direction to open damper **19**.

As damper **19** moves in a counterclockwise direction, wiper **46** of potentiometer **45** simultaneously moves in the same direction, the position thereof being related to the position of the damper. Double-pole, double throw switch **50** is set for cooling mode operation. Therefore, arm **52** is in a position in which the $+E_s$ control signal will pass through resistor **49** and wiper **46** to line **72**, the magnitude of the signal being proportional to the position of the damper. When the position of the damper has reached an equilibrium point in relation to the temperature of the enclosure, the magnitude of the control signal in line **72**, as determined by the position of wiper **46**, will be equal to the magnitude of the variable voltage control signal regulated by thermal elements **23** and **24** and will thus place operational amplifier **26** in a nonconducting state, turning off motor **43**.

If the temperature of the enclosure has fallen below the setpoint during cooling mode operation, the magnitude of the variable voltage control signal supplied to operational amplifier **26** will be such that a negative polarity control signal will pass from line **71** to line **29**.

The $-E_s$ control signal will pass through diode **28**, thereby energizing relay **30**, thus closing switch **31**.

When switch **31** closes, line voltage will pass to terminal **35** of double-pole, double throw switch **34** and will flow through arm **40** to coil **42**, thus energizing motor **43** to cause shaft **44** to rotate in a clockwise direction.

Wiper **46** of potentiometer **45** will simultaneously move in a clockwise direction. Arm **51** of double-pole, double throw switch **50** will provide a $-E_s$ voltage signal through line **66** and resistor **48** to the wiper. The magnitude of the voltage signal will be determined by the position of the wiper relative to the resistance elements of potentiometer **45**. The variable voltage signal will then flow through line **72** to resistor **54** and operational amplifier **26**. When the magnitude thereof is equal to the magnitude of the variable control signal regulated by thermal elements **23** and **24**, operational amplifier **26** will become non-conductive.

Assume now that the enclosure requires heating. Double-pole, double throw switch **34** will be set so that arm **39** will be in contact with terminal **38**, and arm **40** will be in contact with terminal **36**. If the temperature of the enclosure is below the setpoint, the variable voltage control signal passing through resistor **25** to operational amplifier **26** will be of a magnitude to provide a negative polarity control signal through line **71** to line **29**. The $-E_s$ voltage signal will pass through diode **28**, thereby energizing coil **30** and closing switch **31**.

Line voltage will then pass through terminal **35**, terminal **38**, and arm **39**, to energize coil **41**, thereby causing motor **43** to rotate in a counterclockwise direction to open damper **19** as is desired to obtain a greater quantity of treated air. Wiper **46** will simultaneously move in a counterclockwise direction. Double-pole, double throw switch **50** is set for heating mode operation. The $-E_s$ voltage signal will pass through line **66**, arm **51**, and resistor **49** to wiper **46**. The variable voltage signal thus generated will then pass through line **72** to resistor **54**, terminating at operational amplifier **26**.

If, during heating mode operation, the temperature of the enclosure rises above the setpoint, the control circuit will operate to close the damper **19** to the proper position for the required quantity of treated warm air.

As shown in the Figure, it may be desirable to regulate the position of more than one damper in response to the sensed temperature in the enclosure. Although not shown, for means of clarity, structure **17** would include an extension serving as an air passage to a second outlet. Such a modification would be particularly employed in multi-room enclosures such as an apartment in an apartment building.

Line **80** would supply the variable control signal from thermal elements **23** and **24** to a second operational amplifier **26'**, having resistor **25'** connected to its first input and resistor **54'** connected to its second input. Switch **81** may be included so that one damper may be inoperable while the other damper is operable.

The remainder of the control circuit for varying the position of the damper in response to the variable control signal is identical to that previously described and has not been shown for purposes of clarity. It should be understood that any number of such dampers, having a single source of treated air, may be similarly controlled.

The invention disclosed herein will permit regulation of the quantity of treated air passing to an enclosure in proportion to the temperature thereof while maintaining the momentum of the treated air being discharged substantially constant. By regulating the position of the damper to control the quantity of treated air being discharged into the enclosure, the fan **16** may remain operative continuously, thus eliminating the prior art difficulties.

If desired, sound attenuating material may be installed on the inner surfaces of the air passage and on the damper.

While we have described and illustrated a preferred embodiment of our invention, it should be understood that the invention is not limited thereto but may be otherwise embodied within the scope of the following claims.

We claim:

1. Air conditioning apparatus for regulating the temperature of air circulating within an enclosure comprising:

A. a structure serving as a housing;

B. heat exchange means disposed in said housing through which a heat exchange medium is passed;

C. a fan for supplying a quantity of air flow in heat transfer relation with the heat exchange medium passing through said heat exchange means, a constant speed electric motor operatively connected to said fan to rotate said fan at a constant speed;

D. means defining an outlet from said housing through which the treated air is discharged into the enclosure, said heat exchange means being disposed in the housing between the outlet and the fan;

E. means for sensing the temperature of the air in the enclosure and generating a variable control signal, the magnitude thereof being related to the sensed temperature; and

F. means for receiving the variable control signal and operating in response to said signal to vary the discharge area of said outlet means, said means serving to increase the discharge area when conditions in the enclosure as indicated by the variable control signal require a greater quantity of treated air and serving to decrease the discharge area when conditions in the enclosure as indicated by the variable control signal require a lesser quantity of treated air, static pressure in the housing increasing as the discharge area is decreased and decreasing as the discharge area is increased so that the velocity of the treated air discharged from said outlet is increased as the quantity of air discharged is decreased and is decreased as the quantity of air discharged from said outlet is increased to maintain a substantially constant discharge momentum; said means for receiving said variable control signal including an operational amplifier, and first and second diodes, said first diode permitting only passage of a positive polarity voltage and said second diode permitting only passage of a negative polarity voltage.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,682,381 Dated August 8, 1972

Inventor(s) Raymond L. Eckman et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the grant (only) insert the sheet of drawings showing Figures 1 and 2. Column 6, line 26, cancel "Figure" and insert -- drawing --.

Signed and sealed this 9th day of July 1974.

(SEAL)
Attest:

McCOY M. GIBSON, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

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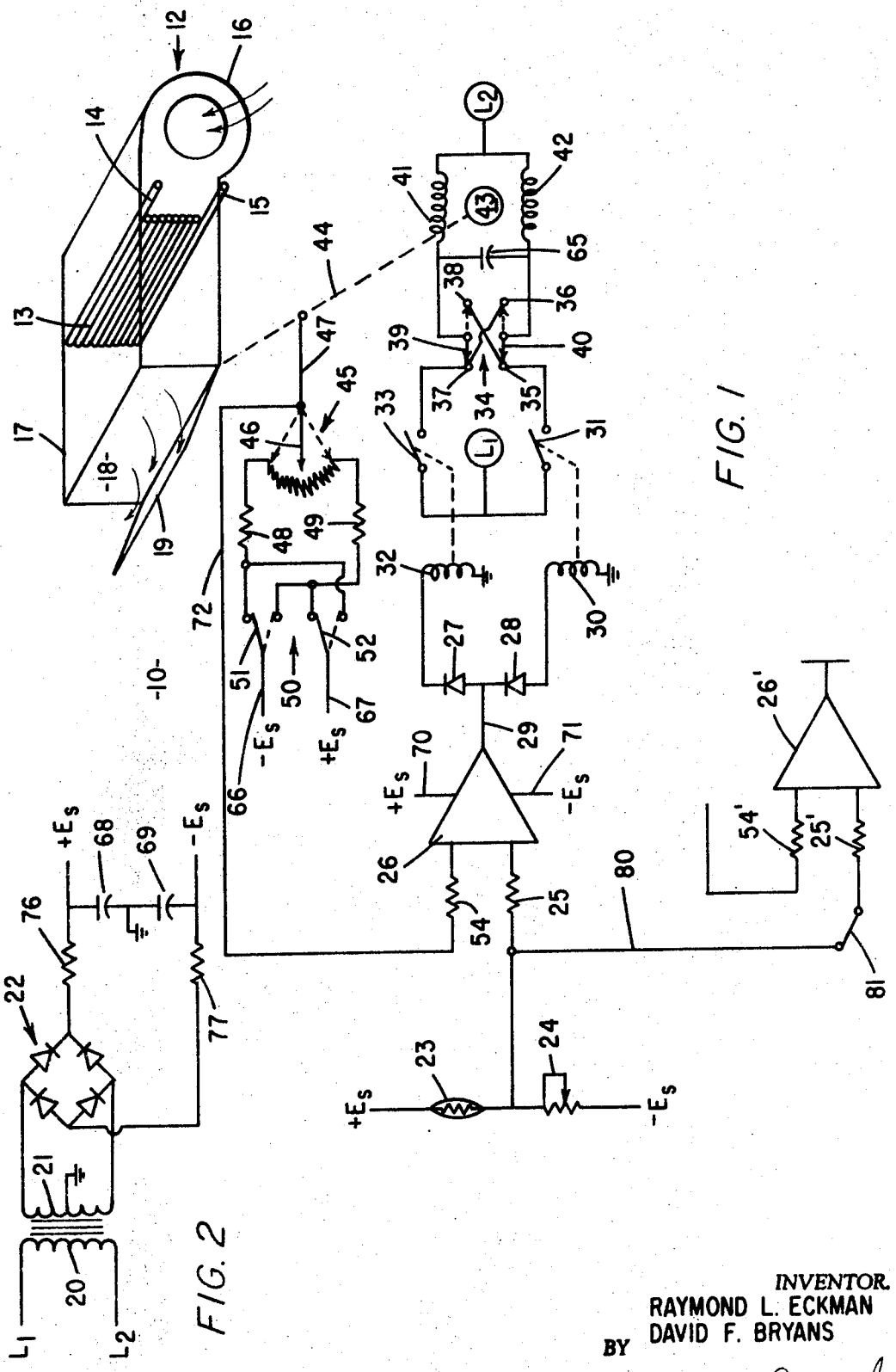


FIG. 1

FIG. 2

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