June 18, 1968 A. P. KRUPER 3,388,860

AUTOMATIC TEMPERATURE CONTROLS

Filed Aug. 29, 1966

FIG. 1.

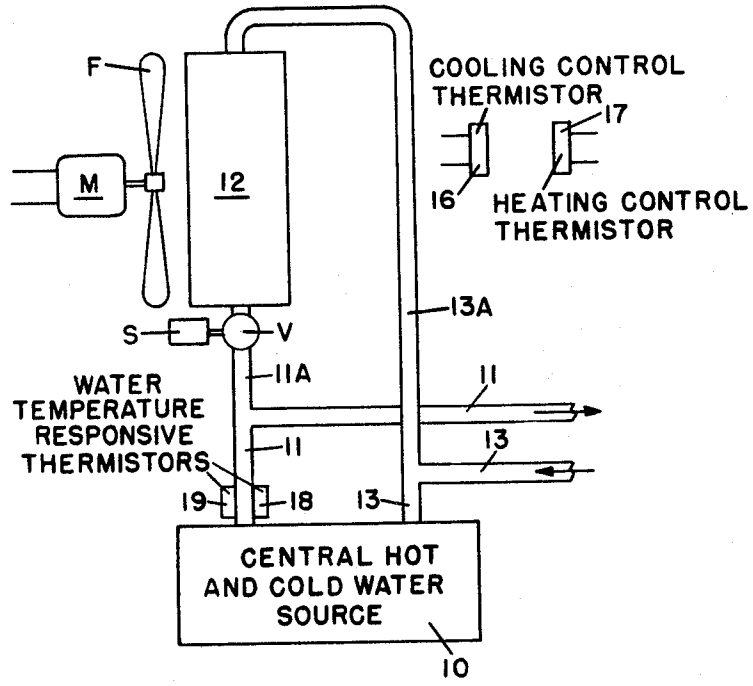
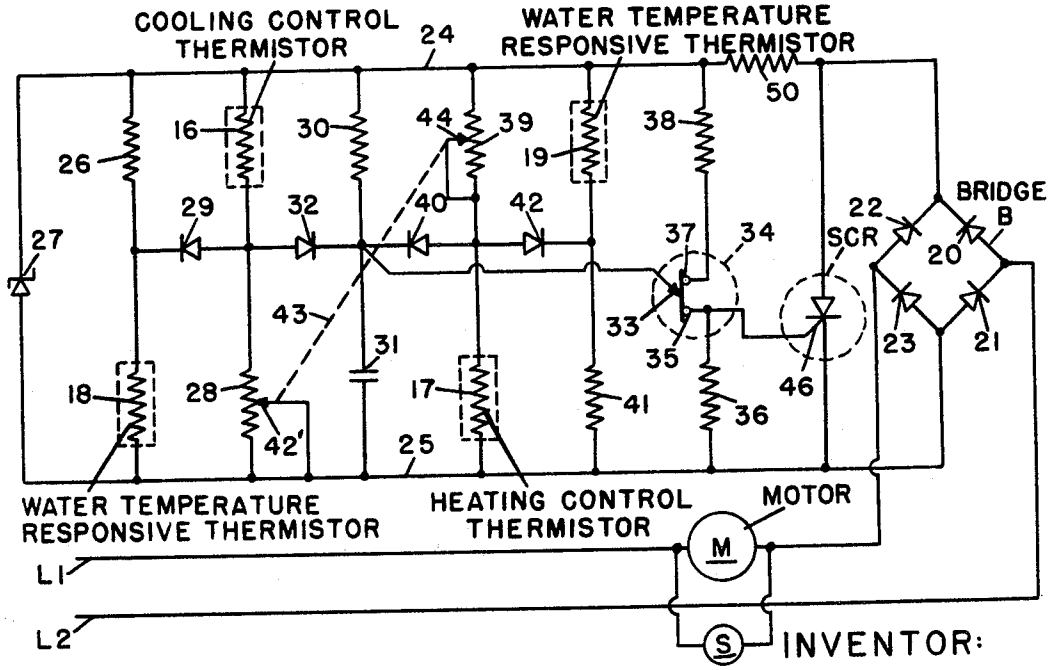


FIG. 2.



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AUTOMATIC TEMPERATURE CONTROLS

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This invention relates to controls for the motors of blowers of, and for the valves of, air cooling and heating units, and has as an object to improve such controls.

The rooms of many modern motels, hotels, and other buildings are cooled in summer by circulating a chilled fluid from a central source through heat exchange coils within the rooms, and are heated in winter by circulating a heated fluid from the central source through the coils. Each coil in each room has a motor-driven blower for circulating the room air, and each room has a thermostat which opens a valve to turn on the cold fluid to its coil, and which closes the valve to turn off the cold fluid to its coil, and starts and stops respectively, its blower motor during cooling operation, and which opens a valve to turn on the hot fluid to its coil, and which closes the valve to turn off the hot fluid to its coil, and starts and stops respectively, its blower motor during heating operation. The speeds of the blower motors can be adjusted by hand only to "lo-med-hi" speeds.

This invention automatically modulates the speed of such a blower motor, and the opening and closing of such a valve, in accordance with the difference between the temperature within a room, and the setting of the room temperature responsive means. During cooling operation, the blower speed and the valve opening increase with increasing room temperature, thereby providing more cooling, and decrease with decreasing room temperature, thereby providing less cooling. During heating operation, the blower speed and the valve opening decrease with increasing room temperature, thereby providing less heating, and increase with decreasing room temperature, thereby providing more heating.

This invention will now be described with reference to the annexed drawings, of which:

FIG. 1 is a diagrammatic view of an air conditioning system embodying this invention, and

FIG. 2 is a circuit schematic of the controls used for varying the speed of the blower motor, and the opening and closing of the valve, of FIG. 1.

Referring first to FIG. 1 of the drawings, a conventional, central source **10** of cold and hot water is connected by a main supply pipe **11**, and a branch supply pipe **11A**, to a heat exchanger **12** in a room of a multi-room building to be cooled or heated. The heat exchanger **12** is connected by a branch, water return pipe **13A**, and a main, water return pipe **13**, to the source **10**. Other heat exchangers in other rooms would be connected by branch pipes to the pipes **11** and **13**. The source **10** may be controlled by an operator to continuously supply cold water through the pipe **11** during summer operation, and to continuously supply hot water through the pipe **11** during winter operation. A blower F, driven by an electric motor M moves room air over the surface of the heat exchanger **12**. A valve V of the modulating type may be connected in the pipe **11A**, and may be variably opened and closed by a conventional solenoid S.

Temperature responsive means such as NTC thermistors **16** and **17** are supported within the room containing the heat exchanger **12**. Temperature responsive means such as NTC thermistors **18** and **19** are in heat exchange contact with the water supply pipe **11**. NTC thermistors have negative temperature coefficients of resistance.

Referring now to FIG. 2 of the drawings, the motor M and the solenoid S are connected in parallel, and to AC

supply line L1, and are connected in series with diode **22**, silicon controlled rectifier SCR, and diode **21** to AC supply line L2. A conventional rectifier bridge B includes the diodes **21** and **22**, and series-connected diodes **20** and **23**. The junction of the diodes **20** and **22** is connected through a resistor **50** to positive DC bus **24**. The junction of the diodes **21** and **23** is connected to minus DC bus **25**. A Zener diode **27** is connected to the busses **24** and **25**, and serves as a voltage regulator.

A fixed resistor **26** is connected to the bus **24**, and in series with the thermistor **18** to the bus **25**. The thermistor **16** is connected to the bus **24**, and in series with variable resistor **28** to the bus **25**. The junction of the resistor **26** and the thermistor **18** is connected through diode **29** to the junction of the thermistor **16** and the resistor **28**. A fixed resistor **30** is connected to the bus **24**, and in series with capacitor **31** to the bus **25**. The junction of the resistor **30** and the capacitor **31** is connected through diode **32** to the junction of the thermistor **16** and the resistor **28**, and to emitter **33** of unijunction transistor **34**. Base terminal **35** of the transistor **34** is connected through fixed resistor **36** to the bus **25**, and to gate **46** of the silicon controlled rectifier SCR. Base terminal **37** of the transistor **34** is connected through fixed resistor **38** to the bus **24**. The thermistor **17** is connected to the bus **25**, and in series with variable resistor **39** to the bus **24**. The junction of the thermistor **17** and the resistor **39** is connected through diode **40** to the junction of the resistor **30** and the capacitor **31**. The thermistor **19** is connected to the bus **24**, and in series with fixed resistor **41** to the bus **25**. The junction of the thermistor **19** and the resistor **41** is connected through diode **42** to the junction of the thermistor **17** and the resistor **39**. Slider **42** of the resistor **28** is electrically connected to the bus **25**, and is mechanically connected by linkage **43** to slider **44** of the resistor **39**. The slider **44** is electrically connected to the junction of the resistor **39** and the thermistor **17**. The sliders **42** and **44** can be adjusted by the linkage **43** to vary the operating points of the thermistors **16** and **17** respectively.

The thermistor **16** is the room cooling control means. The thermistor **17** is the room heating control means. The resistances of the thermistors **16** and **17** decrease with an increase in room temperature, and increase with a decrease in room temperature. The thermistors **18** and **19** respond to the temperature of the water supplied through the pipe **11**. Their resistances increase when cold water is supplied, and decrease when hot water is supplied. The thermistor **19** is used to prevent the heating control thermistor **17** from functioning during cooling operation, and the thermistor **18** is used to prevent the cooling control thermistor **16** from functioning during heating operation.

The resistor **30**, the capacitor **31**, the transistor **34**, the silicon controlled rectifier SCR, the bridge B, and the motor M are connected in a conventional speed control circuit such as is disclosed in the GE SCR Manual, Third Edition, page 132.

Cooling operation

The water in the supply pipe **11** is cold so that the resistances of the thermistors **18** and **19** are high. The resistances of the cooling control thermistor **16** and the resistor **28** with which it is in series, are about equal at medium speed of the motor M, and medium opening of the valve V. The high resistance of the thermistor **18** causes its junction with the resistor **26** to be at a higher voltage than that at the junction of the cooling control thermistor **16** and the resistor **28** so that the diode **29** is back biased so that there can be no flow through it resulting from changes in the resistance of the cooling control thermistor **16**, and there can be flow resulting

from such changes, through the diode 32, to charge the capacitor 31.

The resistances of the resistor 39 and the thermistor 17 are about equal at the medium speed of the motor M, and the medium opening of the valve V. Since the thermistor 19 is cold and has a high resistance, the voltage at the junction of the thermistor 19 and the resistor 41 is lower than that at the junction of the heating control thermistor 17 and the resistor 39 so that the diode 42 is forward biased and conducts, shunting current away from the heating control thermistor 17. The voltage at the junction of the resistor 39 and the thermistor 17 is lower than that at the junction of the resistor 28 and the cooling control thermistor 16 so that the diode 40 is back biased. The voltage at the junction of the resistor 30 and the capacitor 31 is higher than that at the junction of the thermistor 17 and the resistor 39. Thus, the heating control thermistor 17 is effectively disabled.

The voltage at the junction of the cooling control thermistor 16 and the resistor 28 is equal to the resistance of the resistor 28 divided by the sum of the resistances of the thermistor 16 and the resistor 28, multiplied by the voltage between the busses 24 and 25. An increase in room temperature causes the resistance of the thermistor 16 to decrease, increasing the voltage at the junction of the thermistor 16 and the resistor 28, charging through the diode 32, the capacitor 31 to a higher initial voltage which added to the voltage applied from the positive bus 24, through the resistor 30, to the capacitor 31 during each half-cycle, causes the transistor 34 to conduct earlier during each half-cycle. When the transistor 34 conducts, it discharges the capacitor 31 into the gate 46 of the silicon controlled rectifier SCR, causing the latter to conduct and to supply current to the motor M to speed it up conformably with the increase in room temperature, and to supply current to the solenoid S to cause it to increase the opening of the valve V conformably with the increase in room temperature.

A decrease in room temperature causes the resistance of the cooling control thermistor 16 to increase, decreasing the voltage at the junction of the thermistor 16 and the resistor 28, decreasing the voltage at the junction of the resistor 30 and the capacitor 31, charging the latter to a lower initial value so that the transistor 34 is caused to conduct later during each half-cycle, causing the silicon controlled rectifier to conduct later during each half-cycle, decreasing the speed of the motor M, and decreasing the opening of the valve V conformably with the decrease in room temperature.

Heating operation

The water in the supply pipe 11 is hot so that the resistances of the thermistors 18 and 19 are low. The resistances of the heating control thermistor 17 and the resistor 39 are about equal at medium motor speed and medium valve opening. The decreased resistance of the thermistor 19 causes its junction with the resistor 41 to be at a higher voltage than that at the junction of the thermistor 17 and the resistor 39 so that the diode 42 is back biased so that there can be no current flow through it resulting from changes in the resistance of the heating control thermistor 17, and there can be current flow resulting from such changes, through the diode 40 to charge the capacitor 31.

The resistance of the resistor 28 and the thermistor 16 are about equal at medium motor speed and medium valve opening. Since the thermistor 18 is hot and has a low resistance, the voltage at its junction with the resistor 26 is lower than that at the junction of the cooling control thermistor 16 and the resistor 28, so that the diode 29 is forward biased and conducts, shunting current from the cooling control thermistor 16. The voltage at the junction of the resistor 28 and the thermistor 16 is lower than that at the junction of the heating control thermistor 17 and the resistor 39 so that the diode 32 is back biased. The voltage at the junction of the resistor 30 and the capacitor 31 is higher than that at the junction of the thermistor 16 and the resistor 28. Thus, the cooling control thermistor 16 is effectively disabled.

The voltage at the junction of the heating control thermistor 17 and the resistor 39 is equal to the resistance of the thermistor 17 divided by the sum of the resistances of the thermistor 17 and the resistor 39, multiplied by the voltage between the busses 24 and 25. An increase in room temperature causes the resistance of the thermistor 17 to decrease, decreasing the voltage at the junction of the thermistor 17 and the resistor 39, resulting in the capacitor 31 being charged through the diode 40 to a lower initial voltage which added to the voltage applied from the positive bus 24, through the resistor 30 during each half-cycle, causes the transistor 34 and the silicon controlled rectifier SCR to conduct later during each half-cycle, thereby reducing the speed of the motor M, and the opening of the valve V, conformably with the increase in room temperature.

A decrease in room temperature causes the resistance of the heating control thermistor 17 to increase, increasing the voltage at the junction of the thermistor 17 and the resistor 39, increasing the voltage at the junction of the resistor 30 and the capacitor 31, charging the capacitor 31 to a higher initial voltage so that the transistor 34 and the silicon controlled rectifier SCR are caused to conduct earlier during each half-cycle, and increasing the speed of the motor M, and the opening of the valve V, conformably with the decrease in room temperature.

Each room in a multi-room building served by a central source of hot and cold fluid, could have its temperature controlled as described in the foregoing in connection with a single room.

While NTC thermistors have been disclosed as temperature sensing and control means, PTC thermistors, and modulating thermostats of the bellows or diaphragm type which vary electrical resistances with changes in temperature as disclosed in Patent No. 3,264,839 of J. R. Harnish, could be used with appropriate changes in the circuit of FIG. 2. The water temperature responsive thermistors could be replaced with on-off thermostats with appropriate changes in the circuit of FIG. 2.

While the valve V has been disclosed as a modulating valve, it could be an on-off valve, being opened at currents above a predetermined current through its solenoid S, and being closed at currents below the predetermined current.

What is claimed is:

1. An air temperature control system comprising a heat exchanger, supply means for selectively supplying said exchanger with a cooling fluid or a heating fluid, a blower for moving air over the surface of said exchanger, an electric motor for driving said blower, electric supply connections, air temperature responsive means, and means including said responsive means connected to said motor and to said connections for increasing the speed of said motor on an increase in air temperature, and decreasing the speed of said motor on a decrease in air temperature, when cooling fluid is supplied by said supply means to said exchanger, and for decreasing the speed of said motor on an increase in air temperature, and increasing the speed of said motor on a decrease in air temperature, when heating fluid is supplied by said supply means to said exchanger.

2. A system as claimed in claim 1 in which said means connected to said motor and to said connections includes means responsive to the temperature of the fluid supplied by said supply means to said exchanger.

3. An air temperature control system comprising a heat exchanger, supply means for selectively supplying said exchanger with a cooling fluid or a heating fluid, a blower for moving air over the surface of said exchanger, an electric motor for driving said blower, electric supply connections, first air temperature responsive means, second air temperature responsive means, means for dis-

abling said first responsive means when cooling fluid is supplied by said supply means to said exchanger and for disabling said second responsive means when heating fluid is supplied by said supply means to said exchanger, and means including said second responsive means connected to said motor and to said connections for increasing the speed of said motor on an increase in air temperature, and decreasing the speed of said motor on a decrease in air temperature, when cooling fluid is supplied by said supply means to said exchanger, and including said first responsive means connected to said motor and to said connections for decreasing the speed of said motor on an increase in air temperature, and increasing the speed of said motor on a decrease in air temperature, when heating fluid is supplied by said supply means to said exchanger.

4. A system as claimed in claim **3** in which said means for disabling said first and second responsive means comprises means responsive to the temperature of the fluid supplied by said supply means to said exchanger.

5. An air temperature control system comprising a heat exchanger, supply means for selectively supplying said exchanger with a cooling fluid or a heating fluid, a blower for moving air over the surface of said exchanger, an electric motor for driving said blower, AC supply connections, rectifier means, a solid-state switch connected in series with said rectifier means and said motor to said connections, said switch having a gate which causes said switch to conduct during a portion of each half-cycle when current is applied to said gate, air temperature responsive means, and means including said responsive means for causing current to be applied to said gate to cause conduction of said switch for longer periods of time during half-cycles on an increase in air temperature, and for causing current to be applied to said gate to cause conduction of said switch for shorter periods of time during half-cycles on a decrease in air temperature, when cooling fluid is supplied by said supply means to said exchanger, and for causing current to be applied to said gate to cause conduction of said switch for shorter periods of time during half-cycles on an increase in air temperature, and for causing current to be applied to said gate to cause conduction of said switch for longer periods of time during half-cycles on a decrease in air temperature, when heating fluid is supplied by said supply means to said exchanger.

6. A system as claimed in claim **5** in which said means including said responsive means includes means responsive to the temperature of the fluid supplied by said supply means to said exchanger.

7. A system as claimed in claim **5** in which said means for causing current to be applied to said gate includes a transistor which is arranged to supply current to said gate when said transistor conducts, and in which said means including said responsive means includes means for causing said transistor to conduct earlier during each half-cycle on an increase in air temperature, and to conduct later during each half-cycle on a decrease in air temperature, when cooling fluid is supplied by said supply means to said exchanger, and for causing said transistor to conduct later during each half-cycle on an increase in air temperature, and to conduct earlier during each half-cycle on a decrease in air temperature, when a heating fluid is supplied by said supply means to said exchanger.

8. A system as claimed in claim **5** in which said supply means includes a fluid supply pipe connected to said exchanger, in which a valve is connected in said pipe, in which electric means is provided for adjusting said valve towards open position on an increase in current through said electric means, and for adjusting said valve towards closed position on a decrease in current through said electric means, and in which said electric means is connected in series with said solid-state switch and said rectifier means.

9. A system as claimed in claim **8** in which said means including said responsive means includes means responsive to the temperature of the fluid flowing through said pipe.

10. A system as claimed in claim **7** in which said means including said responsive means includes means responsive to the temperature of the fluid supplied by said supply means to said exchanger.

11. An air temperature control system comprising a heat exchanger, supply means for selectively supplying a cooling fluid or a heating fluid to said exchanger, a blower for moving air over the surface of said exchanger, an electric motor for driving said blower, AC supply connections, rectifier means, a solid-state switch connected in series with said rectifier means and said motor to said connections, said switch having a gate which causes said switch to conduct during a portion of each half-cycle when current is applied to said gate, means including a transistor arranged to apply current to said gate when said transistor conducts, first and second air temperature responsive means, each comprising a resistor having a resistance which varies with temperature, means for disabling said first responsive means when a cooling fluid is supplied by said supply means to said exchanger, means for disabling said second responsive means when a heating fluid is supplied by said supply means to said exchanger, means including said second responsive means for causing said transistor to conduct earlier during each half-cycle on an increase in air temperature, and to conduct later during each half-cycle on a decrease in air temperature, when cooling fluid is supplied by said supply means to said exchanger, and means including said first responsive means for causing said transistor to conduct later during each half-cycle on an increase in air temperature, and to conduct earlier during each half-cycle on a decrease in air temperature, when a heating fluid is supplied by said supply means to said exchanger.

12. A system as claimed in claim **11** in which said supply means includes a fluid supply pipe connected to said exchanger, in which a valve is connected in said pipe, in which electric means is provided for adjusting said valve towards open position on an increase in current through said electric means, and for adjusting said valve towards closed position on a decrease in current through said electric means, and in which said electric means is connected in series with said solid-state switch and said rectifier means.

13. A system as claimed in claim **12** in which said disabling means includes means responsive to the temperature of the fluid supplied by said supply means through said pipe to said exchanger.

14. A system as claimed in claim **11** in which said disabling means includes means responsive to the temperature of the fluid supplied by said supply means to said exchanger.

15. A system as claimed in claim **14** in which said first and second responsive means are thermistors.

16. A system as claimed in claim **13** in which said first and second responsive means are thermistors.

17. A system as claimed in claim **11** in which said first and second responsive means are thermistors.

18. An air temperature control system comprising a heat exchanger, supply means for selectively supplying a cooling fluid or a heating fluid to said exchanger, a blower for moving air over the surface of said exchanger, an electric motor for driving said blower, AC supply connections, rectifier means, a solid-state switch connected in series with said rectifier means and said motor to said connections, said switch having a gate which causes said switch to conduct during a portion of each half-cycle when current is applied to said gate, a capacitor, a transistor connected to said capacitor and said gate so as to discharge said capacitor into said gate when said transistor conducts, said transistor having a control electrode connected to said capacitor, means for supplying

a DC voltage during each half-cycle to said control electrode, first and second air temperature responsive thermistors, means including said second thermistor for providing an initial voltage on said capacitor which increases with increases in air temperature and decreases with decreases in air temperature when a cooling fluid is supplied by said supply means to said exchanger, means including said first thermistor for providing an initial voltage on said capacitor which decreases with increases in air temperature and increases with decreases in air temperature when a heating fluid is supplied by said supply means to said exchanger, third and fourth thermistors responsive to the temperature of the fluid supplied by said supply means to said exchanger, means including said third thermistor for disabling said first thermistor when cooling fluid is supplied by said supply means to said exchanger, and means including said fourth thermistor for disabling said second thermistor when heating fluid is supplied by said supply means to said exchanger.

19. A system as claimed in claim 18 in which said supply means includes a fluid supply pipe connected to said exchanger, in which a valve is connected in said pipe, in which electric means is provided for adjusting said valve towards open position on an increase in current through said electric means, and for adjusting said valve towards closed position on a decrease in current through said electric means, and in which said electric means is connected in series with said solid-state switch and said rectifier means.

20. An air temperature control system comprising a heat exchanger, supply means including a fluid supply pipe for selectively supplying a cooling fluid or a heating fluid to said exchanger, a valve in said pipe, electric means for adjusting said valve towards open position on an increase in current through said electric means and for adjusting said valve towards closed position on a decrease in current through said electric means, AC supply connections, rectifier means, a solid-state switch connected in series with said rectifier means and said electric

means to said connections, said switch having a gate which causes said switch to conduct during a portion of each half-cycle when current is applied to said gate, means including a transistor arranged to apply current to said gate when said transistor conducts, first and second air temperature responsive means, each comprising a resistor having a resistance which varies with temperature, means for disabling said first responsive means when a cooling fluid is supplied by said supply means to said exchanger, means for disabling said second responsive means when a heating fluid is supplied by said supply means to said exchanger, means including said second responsive means for causing said transistor to conduct earlier during each half-cycle on an increase in air temperature, and to conduct later during each half-cycle on a decrease in air temperature, when cooling fluid is supplied by said supply means to said exchanger, and means including said first responsive means for causing said transistor to conduct later during each half-cycle on an increase in air temperature, and to conduct earlier during each half-cycle on a decrease in air temperature, when a heating fluid is supplied by said supply means to said exchanger.

21. A system as claimed in claim 20 in which said responsive means are thermistors, in which said means for disabling said second responsive means comprises a third thermistor responsive to the temperature of the fluid supplied by said supply means to said exchanger, and in which said means for disabling said first responsive means comprises a fourth thermistor responsive to the temperature of the fluid supplied by said supply means to said exchanger.

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EDWARD J. MICHAEL, *Primary Examiner.*