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[72] Inventors **Douglas W. De Werth**
Cleveland;
Earl J. Weber, Bay Village, Ohio

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[73] Assignee **Dover Corporation**
Louisville, Ky.

[54] **RESISTANCE-SENSING SYSTEM WITH FAIL-SAFE CIRCUIT**
7 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** **307/252Q,** 307/310, 317/33, 317/148.5, 328/3
[51] **Int. Cl.** **H03k 17/00**
[50] **Field of Search** 307/202, 252, 310; 317/33, 148.5; 328/3

[56] **References Cited**

UNITED STATES PATENTS

3,390,275 6/1968 Baker 307/252X

Primary Examiner—Donald D. Forrer
Assistant Examiner—John Zazworsky
Attorney—Howson and Howson

ABSTRACT: A control circuit suitable for use in a forced-draft gas-fired heating system permits a solenoid gas valve to be turned on only if a blower is operating. The solenoid of the gas valve is controlled by a silicon-controlled rectifier (SCR) which receives its gate signal from a thermistor circuit. The blower, when operating, blows air over the thermistor to limit the extent to which it heats up in response to current passed through it, thereby maintaining the thermistor resistance high enough to operate the SCR and the gas valve so long as the blower operates properly. If the blower does not operate properly, the thermistor warms up further, its resistance decreases markedly, and the signal which it develops and applies to the gate of the SCR becomes too weak to turn on the SCR and the gas valve. To prevent operation of the gas valve should the thermistor become open-circuited, there is employed a second silicon-controlled rectifier circuit comprising a second SCR having anode and cathode electrodes in shunt with the thermistor and having a gate electrode which derives its voltage from across the thermistor by way of a capacitor having a predetermined minimum value sufficient to cause the second SCR to turn on before the first SCR should the thermistor become open-circuited. When the second SCR is thus turned on, the first SCR cannot be turned on, and the solenoid gas valve is thereby prevented from being turned on if the thermistor becomes open-circuited.

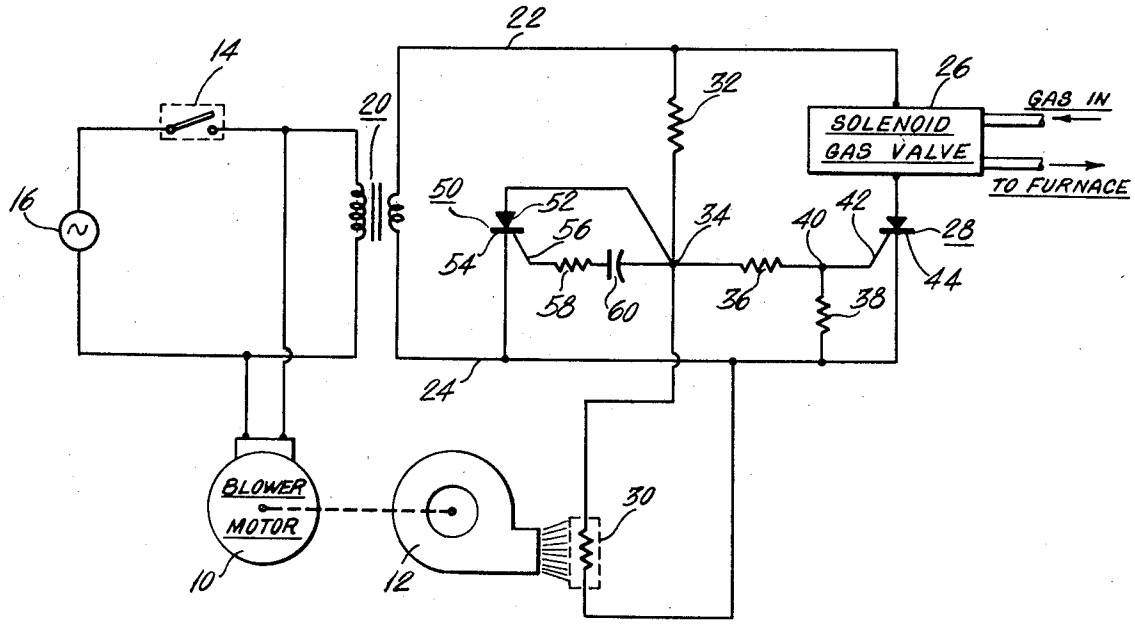
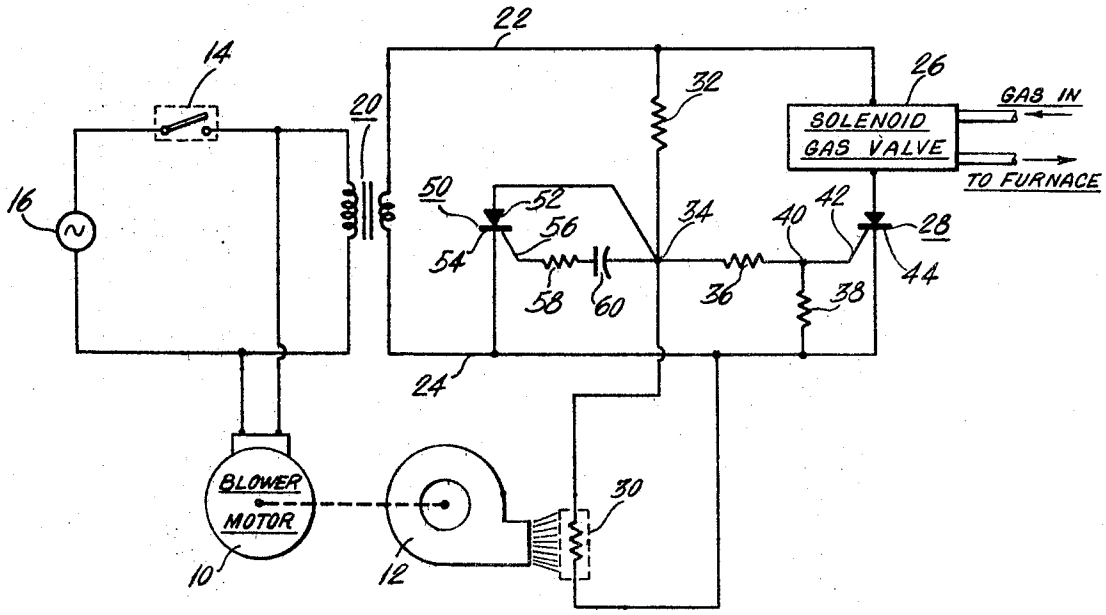


FIG. 1.



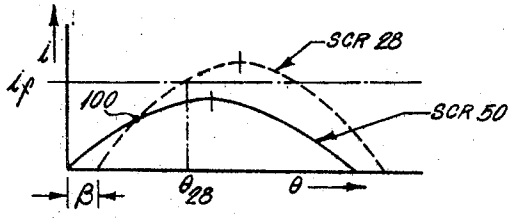


FIG. 2A.

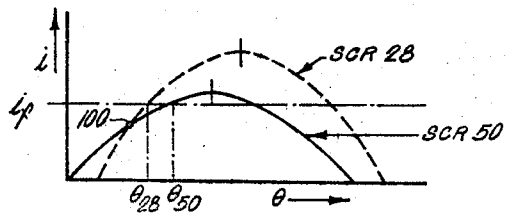


FIG. 2B.

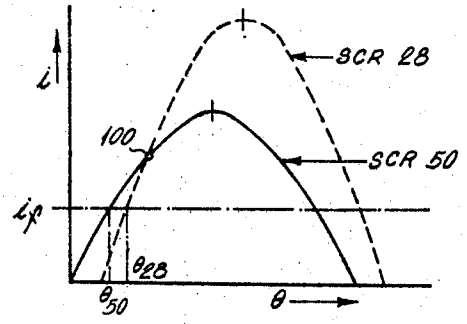


FIG. 2C.

INVENTORS;
DOUGLAS W. DE WERTH
EARL J. WEBER
BY
Howson & Howson
ATTS.

RESISTANCE-SENSING SYSTEM WITH FAIL-SAFE CIRCUIT

BACKGROUND OF THE INVENTION

This invention relates to a resistance-sensing circuit suitable for sensing a flow of a fluid adjacent a temperature-sensitive resistive element. In its more specific aspects it relates to such a circuit for controlling the supply of gaseous fuel through a solenoid-operated valve so as to prevent turning on of the valve when an associated air-blower is not operating properly.

The above-identified type of apparatus is useful in a variety of applications. For example, it is useful in connection with a gas-fired forced-draft heating system in which it is desired to supply gaseous fuel to a gas furnace only so long as the forced-draft blower is operating. In such a system, the operation of the blower may be sensed by placing a thermistor having a negative temperature-coefficient-of-resistance in the normal path of air from the blower, and by passing an electric current through the thermistor when the blower is to be operated. If the blower does not in fact operate, the current through the thermistor will cause the temperature of the thermistor to rise substantially above room temperature, and above the normal operating temperature of the thermistor when the blower is operating properly. This rise in temperature of the thermistor will cause its electrical resistance to decrease below normal. Accordingly, the failure of the blower to operate when desired will be indicated by an abnormal decrease in the resistance of the thermistor, which may be sensed by a resistance-sensing circuit to produce a resistance-indicating signal used to prevent the opening of the valve under these conditions.

To accomplish such operation, the solenoid of the gas valve may be connected in series with the anode-cathode path of a semiconductor controlled rectifier, and the resistance-indicating signal from the thermistor may be applied between gate and cathode electrodes of the semiconductor-controlled rectifier. To produce a signal indicative of the thermistor resistance, the thermistor is connected as one leg of a voltage divider circuit across which a supply voltage is applied, to produce a heating current through the thermistor and to develop across the thermistor a voltage which is sufficiently high to turn on the semiconductor controlled rectifier only when the thermistor resistance exceeds a predetermined value which it exhibits when cooled by the blower. When the thermistor is heated above its normal temperature range due to failure of the blower to operate, its electrical resistance decreases correspondingly and the signal applied between gate and cathode of the semiconductor controlled rectifier becomes insufficient to permit operation of the solenoid gas valve.

Such a circuit in itself is subject to the limitation that if the thermistor becomes open-circuited, its apparent resistance will become and remain very high regardless of its temperature, and the resistance-indicating signal will cause the solenoid gas valve to turn on whether or not the blower is operating. Such open-circuit failure of the thermistor would therefore permit supply of gaseous fuel to the gas furnace even if the blower were not operating properly. Particularly since the thermistor is often situated at a remote location at the end of a pair of connecting leads, which may be broken inadvertently, the possibility that the thermistor may become open-circuited cannot be safely ignored. The type of circuit thus far described must therefore be considered as capable of malfunctioning in a manner such as to permit supply of gaseous fuel to the gas furnace even though the blower is not operating properly.

Accordingly it is an object of the invention to provide a new and useful resistance-sensing circuit.

Another object is to provide such a circuit incorporating certain fail-safe features.

A further object is to provide such a circuit in which the resistance being sensed is that of a resistor of negative temperature coefficient, and which discriminates among lower values of resistance of the resistor, medium or normal values of said resistor, and higher values of said resistor.

It is also an object to provide an electrical system for controlling actuation of a solenoid gas valve so as to prevent operation of said valve unless an air blower is operating to cool an adjacent thermistor, and in which the solenoid gas valve is prevented from opening should the thermistor become open-circuited.

A still further object is to provide a circuit of the latter type in which the solenoid gas valve is actuatable by current in the anode-cathode path of a semiconductor controlled rectifier, the gate electrode of which rectifier is supplied with actuating signals to turn on the rectifier only when the thermistor resistance increases above a predetermined level, the circuit including fail-safe circuitry so that when the thermistor becomes open-circuited the silicon-controlled rectifier is not actuated.

SUMMARY OF THE INVENTION

These and other objects of the invention are achieved by the provision of a system comprising first semiconductor-controlled rectifier means, second semiconductor-controlled rectifier means, variable resistance means the resistance of which it is to be sensed, means for producing across said variable resistance means an alternating voltage which varies with the resistance value of said resistance means, a first gate circuit for connecting said variable resistance means between said first gate and cathode electrodes, a second gate circuit for connecting said variable resistance means between said second gate and cathode electrodes, means connecting said second anode and cathode electrodes in parallel with said first gate and cathode electrodes whereby occurrence of the conductive state in said second rectifier means prevents turning on of said first rectifier means, and means for sensing the occurrence of the conductive state in said first rectifier means, said second gate circuit supplying to said second gate electrode a current advanced in phase and reduced in peak amplitude compared to that supplied to said first gate electrode.

In a preferred embodiment the invention comprises first resistance means having a value of resistance variable above and below a predetermined first value, second resistance means in series with said first resistance means, means for applying an alternating voltage across the series combination of said first and second resistance means, first semiconductor controlled means having anode, cathode and gate electrodes, third resistance means connecting the gate-to-cathode path in said first semiconductor rectifier means in parallel with said first resistance means, second semiconductor controlled rectifier means having an anode, cathode and gate electrodes, means connecting the anode-to-cathode path in said second semiconductor-controlled rectifier in parallel with said first resistance means, and capacitive means connecting said gate-to-cathode path in said second semiconductor-controlled rectifier means in parallel with said first resistance means, whereby said first semiconductor-controlled rectifier is substantially nonconductive when the resistance of said first resistance means is below said predetermined first value, becomes conductive when the resistance of said first resistance means rises above said predetermined first value, and is nonconductive when the resistance of said first resistance means rises above a predetermined second value greater than said first value for which said second semiconductor-controlled rectifier becomes conductive. Where the first resistance means is a thermistor, said first semiconductor-controlled rectifier may be rendered conductive to turn on a device such as a solenoid gas valve so long as the resistance of the thermistor remains above said predetermined first value but below said second value. By placing the thermistor in the path of air from a blower, the first semiconductor-controlled rectifier can be caused to turn on to enable opening of the solenoid-controlled gas valve only when the blower is operating, and not when the blower is off or the thermistor open-circuited. Accordingly, chance open-circuiting of the thermistor leads, for example, will not permit the gas valve to be turned on by the first semiconductor-controlled rectifier means, and fail-safe operation is thereby provided.

BRIEF DESCRIPTION OF FIGURES

These and other objects and features of the invention will be more readily understood from a consideration of the following detailed description, taken in connection with the accompanying drawings, in which:

FIG. **1** is a schematic diagram, partly in block form, of one preferred embodiment of the invention, and FIGS. **2A**, **2B** and **2C** are graphical representations to which references will be made in explaining the theory and operation of the invention.

DESCRIPTION OF SPECIFIC EXAMPLES

Referring now to the specific example of the invention illustrated in FIG. **1** by way of example only, there is shown a blower motor **10** which operates an air blower **12** whenever switch **14** is closed to supply alternating current to blower motor **10** from alternating-current power source **16**. Switch **14** may be a manually-operable switch, or may be a thermostatic switch for turning on the blower motor only when the ambient temperature falls below a predetermined value, as in the usual gas-fired forced-draft home heating system.

When switch **14** is closed to supply power to blower motor **10**, AC voltage is also supplied, by way of stepdown transformer **20**, to the transformer secondary leads **22** and **24**. The latter leads are connected to opposite ends of the series combination formed by a solenoid gas valve **26** and the anode-to-cathode path of a semiconductor-controlled rectifier **28**. The solenoid gas valve **26** may be of any conventional type having an electrical winding which, when supplied with sufficient electrical current, turns on the normally-closed gas valve; typically it may comprise the gas valve for supplying gaseous fuel to a gas furnace for heating air to be circulated by blower **12**. In such a system it is normally important that the gas furnace not operate, and that solenoid gas valve **26** be closed, if and when blower motor **10** is not running for any appreciable length of time. Accordingly, means are provided for sensing the operation of the blower **12** and for preventing opening of the solenoid gas valve **26** unless the blower is operating properly.

The airflow sensing means utilized in this example comprises a thermistor **30** having a negative temperature coefficient of resistance, e.g. the warmer the thermistor gets the lower its electrical resistance becomes. Thermistor **30** is connected as the lower leg of a voltage divider circuit of which resistor **32** comprises the upper leg, the divider being connected between the transformer secondary leads **22** and **24**. Accordingly, the voltage at tap point **34** between fixed-resistor **32** and thermistor **30** tends to vary in the same sense as the resistance of thermistor **30**, and hence inversely with the temperature of thermistor **30**. A gate-biasing voltage-divider circuit comprising resistors **36** and **38** in series is connected across thermistor **30**, and the tap point **40** thereon is connected to the gate electrode of the semiconductor-controlled rectifier **28**.

It will be understood that semiconductor-controlled rectifier **28** is of the usual type in that if its gate-to-cathode voltage is zero it will remain turned off, so that there is substantially no conduction between its anode and cathode electrodes; to turn on semiconductor-controlled rectifier **28**, and thereby to turn on the solenoid gas valve **26**, the voltage of gate electrode **42** of controlled rectifier **28** must become positive with respect to that of its cathode electrode **44** by a substantial amount, typically of the order of one or several volts. The values of the resistors **32**, **36** and **38**, and the resistance of thermistor **30** are all selected in conjunction with the magnitude of the AC voltage between leads **22** and **24** to cause semiconductor-controlled rectifier **28** to be turned on during each cycle of the alternating supply voltage so long as the resistance of thermistor **30** remains above a minimum normal value R_n equal to the minimum value of thermistor resistance produced when the blower is operating normally so as to cool the thermistor. However, the latter values of resistors and thermistor are preferably also selected so that the voltage produced at the gate electrode **42** of semiconductor-controlled rectifier **28** when thermistor **30** has the minimum normal resistance value R_n is just sufficient to insure turning on of semiconductor-controlled rectifier **28**. Accordingly, should the resistance of thermistor **30** decrease appreciably below the value R_n, semiconductor-controlled rectifier **28** will no longer be actuated to its on state. Therefore, should the blower not operate or operate improperly when the switch **14** is closed, so that thermistor **30** is not properly cooled by the flow of air from blower **12**, the resultant drop in resistance of thermistor **30** will prevent operation of semiconductor-controlled rectifier **28** and thereby also prevent opening of solenoid gas valve **26**. In this way the gas furnace supplied with fuel by solenoid gas valve **26** is prevented from operating if blower motor **10** should fail to operate for any reason.

In addition to the circuit elements described in detail hereinabove, there is also employed a second semiconductor-controlled rectifier **50** having its anode electrode **52** and its cathode electrode **54** connected in parallel circuit with thermistor **30**, and having its gate electrode **56** connected by way of a series combination of resistor **58** and capacitor **60** to the tap point **34** between thermistor **30** and divider resistor **32**. So long as thermistor **30** remains in the circuit as shown and has a resistance value in its normal operating range or lower, semiconductor-controlled rectifier **50**, resistor **58**, and capacitor **60** have no substantial effect on the previously-described operation of the circuit. However should the resistance of thermistor **30** increase above a second value R_h substantially higher than the normal value R_n, as will occur if thermistor **30** becomes open-circuited, semiconductor-controlled rectifier **50** will become conductive prior to the times at which rectifier **28** would normally become conductive, and in so doing will reduce the voltage at tap point **34** below that required to fire semiconductor-controlled rectifier **28**; accordingly, the latter device will become nonconductive and solenoid gas valve **26** will be maintained in its closed condition. Thus, for example, if the leads to thermistor **30** are broken, semiconductor rectifier **50** will become conductive and semiconductor-controlled rectifier **28** will become nonconductive to prevent turning on of gas valve **26** and thereby discontinue operation of the gas furnace. In this way operation of the furnace is prevented unless blower motor **10** is operating and thermistor **30** is connected into the circuit properly and has a resistance value in the correct operating range.

Without thereby in any way limiting the scope of the invention, the following specific values of particular components for the circuits shown in the FIG. are given in the interest of complete definiteness. The voltage between transformer secondary leads **22** and **24** may be 24 volts r.m.s. at 60 c.p.s.; upper voltage-divider resistor **32** may have the value of about 2,200 ohms; protective resistor **36** for the gate of semiconductor-controlled rectifier **28** may have a value of about 330,000 ohms; lower voltage-divider resistor **38**, which can be selected to adjust the level of signal applied to the gate of controlled rectifier **28**, may have a value of about 22,000 ohms; protective resistor **58** for the gate of controlled rectifier **50** may have a value of 330,000 ohms; capacitor **60** may have a value of about 0.001 microfarad; thermistor **30** may be a Fenwal type GB41J1 thermistor having a resistance of about 12,000 ohms at 25° Centigrade, decreasing to about 600 ohms at about 100° Centigrade. Solenoid gas valve **26** may have a control winding presenting a resistance of about 4.2 ohms and an impedance at 60 cycles of about 6.2 ohms. The semiconductor controlled rectifiers **28** and **50** may each comprise a General Electric type C106B1 silicon-controlled rectifier. With these values, the circuit shown in the figure operates as described above when thermistor **30** is located in the airstream produced by blower **12**, and serves to prevent turning on of solenoid gas valve **26** unless blower **12** is operating properly and thermistor **30** is connected into the circuit to provide resistances in the normally-to-be-expected range, as opposed to being open-circuited for example.

It has been found that the resistors **38** and **58** are not critical and in fact may be omitted. The value of capacitor **60** is rela-

tively critical in any given application. Thus its value is limited to a predetermined range of values when used in combination with any particular set of values for the parameters of the remaining elements of the system. For the particular circuit values given above, it has for example been found that the value of capacitor **60** should be from about 0.0047 microfarad to about 0.0150 microfarad. If the capacitance of capacitor **60** is substantially below this range, the controlled rectifier **50** does not fire in time to prevent turning on of rectifier **28** when the resistance of thermistor **30** is high, and hence protection against open-circuiting of thermistor **30** is not obtained; on the other hand, if the value of capacitor **60** is greater than about 0.0150 microfarad, controlled rectifier **50** remains on at all times so that gas valve **26** is never operated, thus defeating the object of supplying gaseous fuel when the blower is operating. By experimental variation the upper and lower limits of the permissible range of values of capacitor **60** may readily be determined in view of the foregoing discussion thereof.

While not wishing to be limited by the details of any particular theory, the following is believed to describe correctly certain basic principles of operation of the invention.

In the operation of the circuit, the same voltage developed at point **34** is imposed on the gate circuit of SCR **50** (capacitor **60** and resistor **58**) as on the gate circuit of SCR **28** (resistor **36**). This voltage is equal to the voltage drop across the thermistor **30** and may vary from zero (thermistor **30** shorted) to practically the source voltage (thermistor **30** open).

Because of capacitor **60**, the gate circuit of SCR **50** has a higher impedance than that of SCR **28**. Hence a higher voltage is required at point **34** to trigger SCR **50** than is required for SCR **28**. As the voltage across thermistor **30** is increased (as by cooling by means of the blower), a voltage value is reached at point **34** which just triggers SCR **28**. With a further increase in this voltage both SCR **28** and SCR **50** will be triggered. The fact that SCR **50**, in its conducting condition, shunts out the gate circuit of SCR **28** does not stop SCR **28** from continuing to conduct provided that SCR **28** has been triggered before SCR **50**. This is for the reason that an SCR, once triggered, continues to conduct for the remainder of the anode-voltage half-cycle regardless of the condition of its gate. Actually, when SCR **50** is triggered it also shunts out its own gate circuit.

In general, if SCR **28** is triggered into conduction, SCR **50** may be subsequently triggered. However, if in some other condition SCR **50** is triggered, SCR **28** cannot be subsequently triggered so long as SCR **50** remains conductive. Under the latter conditions, the shunting action of SCR **50** has reduced the gate circuit voltage of SCR **28** to zero before SCR **28** could be triggered. Such a condition exists when thermistor **30** becomes open, or when the voltage at point **34** becomes relatively high. The following explains how SCR **50** can at times be triggered before SCR **28**.

The oscillating gate circuit voltage at point **34** may be described as:

$$V=V_o\sin\Theta$$

where V_o is the peak voltage at point **34** and is dependent on the resistance of thermistor **30**. If the voltages required at point **34** for firing are designated as V_{50} and V_{28} for SCR **50** and SCR **28** respectively, (with $V_{50}>V_{28}$ because of the higher impedance of the gate circuit of SCR **50**), the firing angles, Θ_{50} and Θ_{28}, are:

$$\theta_{50}=\sin^{-1}\frac{V_{50}}{V_o}$$

$$\theta_{28}=\sin^{-1}\frac{V_{28}}{V_o}$$

and

$$\theta_{50}-\theta_{28}=\sin^{-1}\frac{V_{50}}{V_o}-\sin^{-1}\frac{V_{28}}{V_o}$$

This last relationship indicates that the difference between the firing angles (or firing times) becomes less as the gate circuit peak voltage, V_o, increases by virtue of increase in resistance of thermistor **30**.

The gate circuit of SCR **50** contains capacitor **60** in addition to resistor **58**. As a consequence, the current in this circuit leads the voltage at point **34** by an amount dependent on the relative values of elements **60** and **58**. The gate circuit of SCR **28** is entirely resistive, and its current is in phase with the voltage. Therefore, the current in gate circuit SCR **50** leads the current in gate circuit SCR **28**. If V_o is increased to a point where the firing angle difference (Θ_{50}–Θ_{28}) becomes less than the above current lead angle, SCR **50** will trigger into conductance before SCR **28** which, in fact, cannot now be triggered because of the shunting action of conducting SCR **50**.

This same action can also be described from a consideration of current flow with the aid of FIGS. **2A**, **2B** and **2C**, in which currents to the gate electrodes are plotted versus phase angle Θ of the currents, to a common scale. The broken-line curve is for SCR **28** while the solid curve is for SCR **50**. As indicated above, the current through the gate of SCR **50** leads that through the gate of SCR **28** by some angle β because of the capacitor in the gate circuit of SCR **50**. With any given voltage drop across thermistor **30**, the amplitudes of the current curves will be inversely proportional to the impedances of the gate circuits. It is assumed that the two SCR's are quite similar and, hence, require the same firing current i_f. With a very low voltage at point **34**, neither SCR will receive a gate current as great as i_f. With a relatively low voltage condition as represented in FIG. **2A**, only the current to SCR **28** is sufficient to exceed i_f, and only SCR **28** fires. For the somewhat higher voltage condition shown in FIG. **2B**, the firing current i_f is reached at Θ_{28} for SCR **28** at which point SCR **28** becomes conducting. At some time interval later, i_f is reached at Θ_{50} for SCR **50**, at which time this SCR becomes conducting also. For a high voltage condition as represented in FIG. **2C**, such as will occur if thermistor **30** becomes open, the gate current of SCR **50** reaches i_f first at Θ_{50}, at which point SCR **50** begins conducting and prevents SCR **28** from firing thereafter. Actually, the curves would collapse to zero at Θ_{50} in this figure because of the shunting action of SCR **50**. With the current lead angle β fixed by the relative values of capacitor **60** and resistor **58**, and with the relative amplitudes of the curves fixed by the relative impedances of the gate circuits, the crossover point **100** of the curves is shifted to a higher current value as the amplitudes of the curves are increased by virtue of an increase in voltage, at point **34**, hence the above-described result of SCR **50** firing so as to prevent SCR **28** from firing when the crossover point **100** is shifted to above i_f.

If capacitor **60** is increased in value with no other change, the current lead angle β is increased, as is the relative amplitude of the curve for SCR **50** because of decreased impedance in the gate circuit of SCR **50**. Both of these effects shift the crossover point **100** to higher current values. Thus, capacitor **60** can be increased to a value such that the crossover point **100** will always be above i_f; with this condition, SCR **28** would never fire and gas valve **26** would never open.

Conversely, and for similar reasons, a decreased value of capacitor **60** will shift the crossover point **100** downward. Thus capacitor **60** could be made so small that even the high gate circuit voltage produced with thermistor **30** open would not be sufficient to raise the crossover point **100** above i_f. With this condition, SCR **28** will always fire to open gas valve **26** and the device will not function as intended.

It is apparent from this explanation that the same desired function of the device could be obtained by removing capacitor **60** from the gate circuit of SCR **50** and introducing an inductance into the gate circuit of SCR **28** to provide the desired relative phase difference for currents to the two gates. This modification would cause a current lag to the gate of SCR **28** relative to the current to SCR **50**. Thus equivalent performance should be obtained either with a current lag at SCR **28** by virtue of an inductance in its gate circuit, or with a cur-

rent lead to SCR 50 by virtue of a capacitance in its gate circuit.

Accordingly while the invention has been described with particular reference to specific embodiments thereof in the interest of complete definiteness, it will be understood that it may be embodied in a variety of forms diverse from those specifically shown and described, without departing from the invention as defined by the appended claims.

We claim:

1. Fail-safe resistance-sensing means, comprising:
- first semiconductor-controlled rectifier means having first anode, cathode and gate electrodes and biased in a normally nonconductive state;
- second, semiconductor-controlled rectifier means having second anode, cathode and gate electrodes, and biased in a normally nonconductive state;
- means for applying an alternating voltage between the anode and cathode of each of said first and second semiconductor-controlled rectifier means;
- variable resistance means, the resistance of which is to be sensed;
- means for producing across said variable resistance means an alternating voltage varying with the resistance value of said resistance means;
- a first gate circuit for connecting said variable resistance means between said first gate and cathode electrodes to supply said varying voltage to said first gate electrode;
- a second gate circuit for connecting said variable resistance means between said gate and cathode electrodes to supply said varying voltage to said second gate electrode;
- means for connecting said second anode and cathode electrodes in parallel with said first gate and cathode electrodes whereby occurrence of the conductive state in second rectifier means prevents turning on of said first rectifier means; and
- means actuated by the occurrence of the conductive state in said first rectifier means;
- said second gate circuit differing from said first gate circuit so as to supply to said second gate electrode a current advanced in phase and reduced in peak amplitude compared to that applied to said first gate electrode;
- whereby when said varying alternating voltage is less than a first value both of said first and second semiconductor-controlled rectifier means remain in their nonconductive states, when said varying alternating voltage is at least as great as said first value but less than a second value said first semiconductor-controlled rectifier means is rendered conductive by each cycle of said varying alternating voltage, and when said varying alternating voltage is at least as great as said second value said second semiconductor-controlled rectifier means is rendered conductive by each cycle of said varying alternating voltage to prevent said first semiconductor-controlled rectifier from becoming conductive.

2. The apparatus of claim 1, in which said alternating voltage produced across said variable resistance means and said alternating voltage applied between said anodes and cathodes of said rectifier means are of substantially the same form and frequency.

3. Apparatus in accordance with claim 1, in which said first gate circuit comprises a first resistor in series with said first gate electrode, said second gate circuit comprises a capacitor and a second resistor in series with said second gate electrode, and the impedance of said second gate circuit of said varying alternating voltage is greater than that of said first gate circuit.

4. The apparatus of claim 1, wherein said second gate circuit comprises capacitive means for providing said advanced phase of current.

5. The apparatus of claim 1, wherein said means for producing an alternating voltage across said variable resistance means comprises a source of alternating voltage, impedance means in series with said resistance means, and means connecting said source across the series combination of said impedance means and said resistance means.

6. Fluid flow-sensing apparatus comprising:
- thermistor means having a negative temperature coefficient of resistance;
- means for passing a heating current through said thermistor means to heat it and reduce its resistance, whereby a flow of a cooling fluid adjacent said thermistor means will reduce the temperature and increase the resistance of said thermistor means and increase the voltage across said thermistor means;
- first semiconductor-controlled rectifier means having an actuated high-conduction state, a normal low-conduction state, and first anode, cathode and gate electrodes;
- first gate circuit means connecting said thermistor means to said first gate electrode to actuate said first rectifier means to said high-conduction state thereof in response to said voltage when said resistance of said thermistor means is greater than a first predetermined value but less than a second predetermined value and to permit it to assume said low-conduction state thereof when said resistance falls below said first predetermined value;
- second semiconductor-controlled rectifier means having an actuated high-conduction state and a normal low-conduction state, and second anode, cathode and gate electrodes;
- means for applying an alternating voltage between said first anode and cathode electrodes, and between said second anode and cathode electrode;
- means connecting said first gate and cathode electrodes effectively in parallel with said second anode and cathode electrode;
- second gate circuit means connecting said thermistor means to said second gate electrode and having a phase shift characteristic different than that of said first gate circuit means so as to actuate said second semiconductor-controlled rectifier means to its high-conduction state in response to said voltage across said thermistor means and to actuate said first semiconductor-controlled rectifier means to its low-conduction state when said resistance increases beyond said second predetermined value greater than said first predetermined value, whereby operation of said first semiconductor-controlled rectifier means in said high-conduction state thereof in response to opening circuiting of said thermistor means is prevented.

7. Apparatus in accordance with claim 6, in which said first gate circuit means comprises a first resistor in series with said first gate electrode, said second gate circuit means comprises a capacitor and a second resistor in series with said second gate electrode, and the impedance of said second gate circuit means to said varying alternating voltage is greater than that of said first gate circuit.