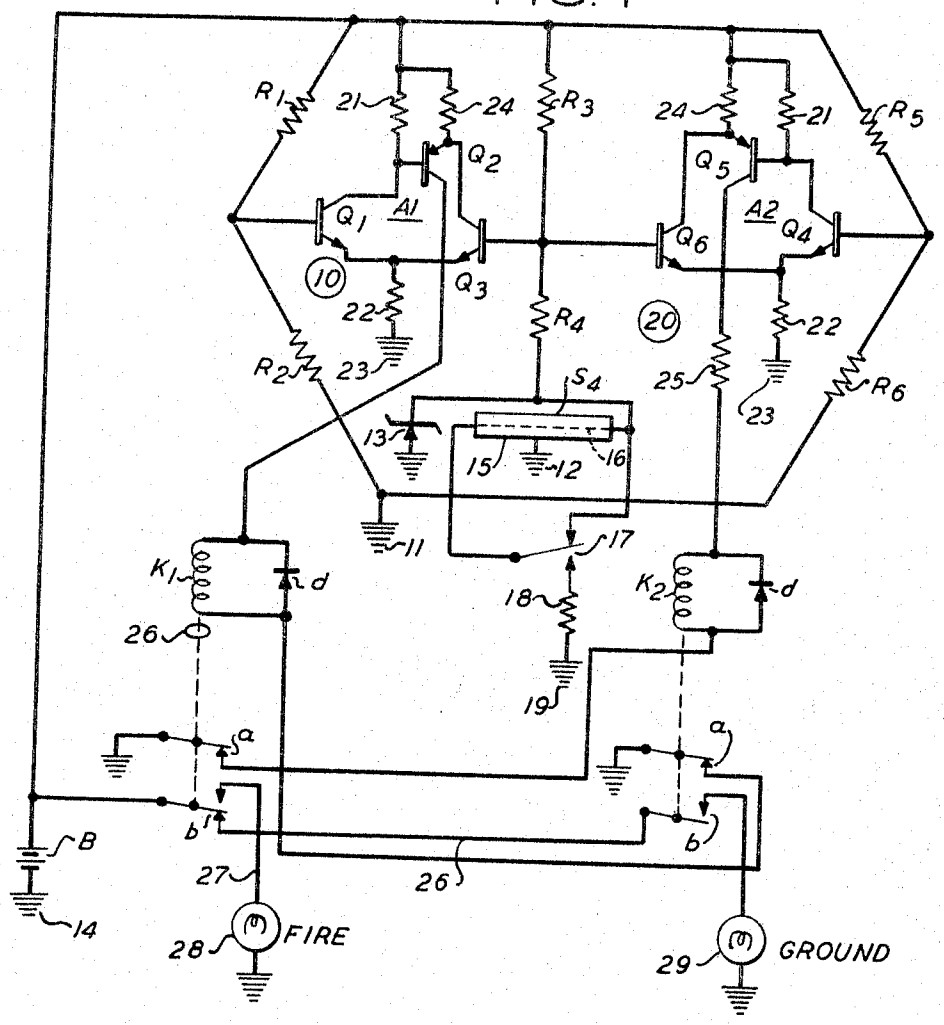
May 16, 1967 W. W. ANDREWS 3,320,602

FIRE DETECTOR SYSTEMS HAVING FALSE ALARM PREVENTION

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FIG. 1



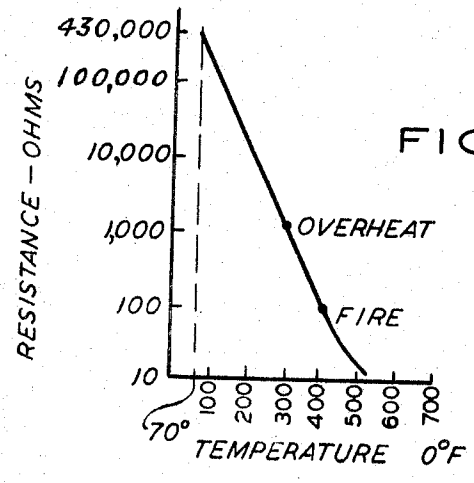


FIG. 3

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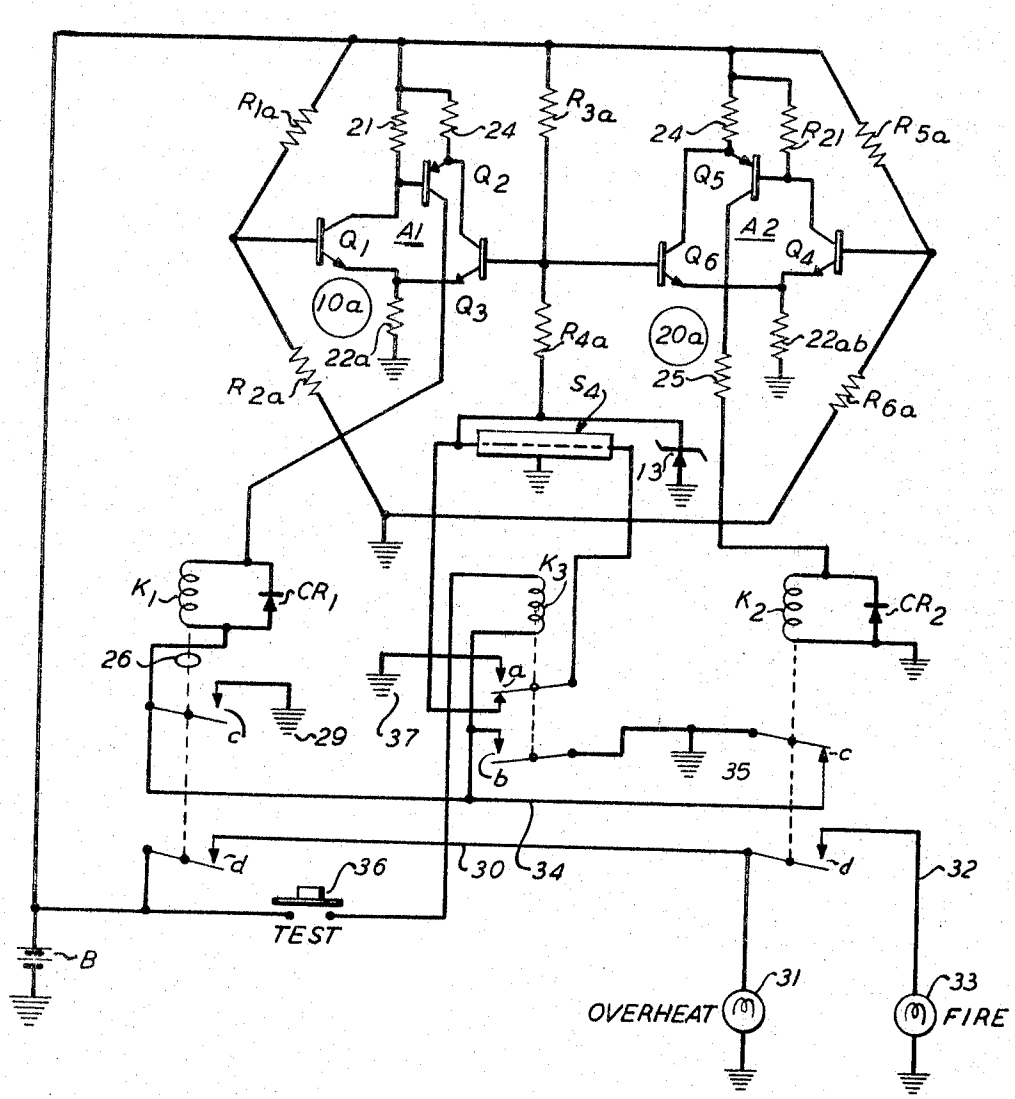
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FIG. 2



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FIRE DETECTOR SYSTEMS HAVING FALSE ALARM PREVENTION

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7 Claims. (Cl. 340—233)

This invention relates to fire detector systems using negative temperature coefficient resistor devices for sensing the presence of overheat or fire conditions, and more particularly it relates to improved forms of such systems which will not give a false alarm should a short circuit develop in the sensing device.

The sensing device in fire detector systems is typically in the form of a cable comprising an outer metallic sheath, a center wire and an intervening semi-conductive material which has a negative temperature coefficient of resistance causing the cable to be essentially an insulator at low temperatures and a low resistance conductor at fire temperatures. Such cable may be of the form described in the Kelly et al. Patent No. 2,740,874, dated Apr. 3, 1956.

The present fire detector systems are intended especially for use on aircraft. In this particular use the sensing cable is subjected to heavy vibration and wide variations in weather conditions which may produce a mechanical breakdown in the cable construction giving rise to a short circuit between the sheath and the center wire or an open circuit between the terminal ends of the center wire. The present invention resides in an improvement whereby such breakdown in the sensing cable will not give rise to a false alarm.

The present invention resides in providing first and second Wheatstone bridge circuits with a common branch including the sensing cable as one arm, in adjusting the two bridge circuits to activate respective relays at overheat and fire warning temperatures or alternatively at fire warning and short circuit conditions, and in delaying the operation of the first relay relative to the second while yet causing the first relay to operate first in response to a heating of the sensing cable but to cause the second relay to operate first in response to a short circuit condition in the sensing cable. Further, the invention provides an inter-control between the two relays so that if the first relay is the first to operate it will provide an overheat or fire warning but that if the second relay is the first to operate it will provide no warning or a warning indicating merely a faulty condition in the equipment which is of a character which could not be construed as a true alarm indicating a fire condition.

It is therefore an object of my invention to provide an improved fire detector system using a sensing device having a negative temperature coefficient of resistance, which will operate dependably to give a fire warning responsive to a fire condition but which will give no fire warning responsive to a fault developing in the sensing device.

Another object is to provide such im proved fire detector system which gives a fire warning responsive to a fire condition and a fault warning responsive to a short circuit in the sensing cable.

Another object is to provide such improved fire detector system with novel means by which it can be readily tested for operability.

These and other objects and features of the invention will be apparent from the following description and dependent claims.

In the description of my invention reference is had to the accompanying drawings, of which:

FIGURE 1 is a schematic circuit diagram of an embodiment of the invention adapted for indicating fire and short circuit conditions;

FIGURE 2 is a similar schematic circuit diagram of another embodiment of the invention with respective alarm circuits for indicating overheat and fire warning conditions; and

FIGURE 3 is a plot of a resistance vs. temperature characteristic of a typical sensing cable with which the invention is used.

The embodiment of my invention shown in FIGURE 1 comprises a first Wheatstone bridge **10** having two branches connected in parallel of which one branch includes fixed resistors R_1 and R_2 as separate arms and the other branch includes a fixed resistor R_3 as one arm and a resistor R_4 in series with a sensing cable S_4 as the other arm. The two branches are connected at their lower ends to respective grounds **11** and **12** and are interconnected at their upper ends and connected through a battery B to ground **14**. The battery B may typically supply **28** volts. The sensing cable comprises an outer sheath **15** and a center wire **16** separated from the sheath by a suitable semi-conductive material having a negative temperature coefficient of resistance. Both ends of the center wire **16** lead out of the sheath to suitable terminals and are interconnected in a loop through a test switch **17** to the resistor R_4. The sheath has permanent connection to the ground **12**. When the test switch **17** is manually operated it disconnects the far end terminal of the center wire **16** from the resistor R_4 and connects the resistor R_4 via the center wire **16** and resistor **18** to a ground **19**. The sum of the resistances of the center wire **16** from one end to the other end of the resistor **18** is made less than 100 ohms—the resistance of the sensing cable at which the bridge **10** is balanced—and is made greater than 40 ohms—the resistance of the sensing cable at which the bridge **20** is balanced. For example, the resistance of the center wire **16** may be 30 ohms and that of the resistor **18** may be 40 ohms. A zener diode **13** is connected across the detector cable S_4 to ground to limit tht voltage across the cable when the cable is not heated and is at its highest resistance.

The present fire detector system further includes a second Wheatstone bridge **20** having two branches connected in parallel of which one branch is in common with the branch of the bridge **10** comprising the resistor arms R_3 and R_4–S_4, and the other branch includes fixed resistors R_5 and R_6 as separate arms. The branch R_5 and R_6 is connected to ground **11** at one end and to the battery B at the other end, the same as the branch R_1 and R_2 of the bridge **10**.

Connected diagonally across the bridge **10** is an output circuit comprising an emitter-coupled differential transistor amplifier A_1 feeding into a first relay K_1. Transistor amplifier A_1 includes a first transistor Q_1 of NPN type having a base electrode connected to the junction between the resistors R_1 and R_2, a collector electrode connected through a resistor **21** to the battery B and an emitter electrode connected through a resistor **22** to ground **23**. The collector electrode of transistor Q_1 is also connected directly to the base of an output transistor as of PNP type having its emitter electrode connected through a resistor **24** to the battery B and its collector electrode connected to the relay K_1. Another transistor Q_3 of the NPN type has its base electrode connected to the junction between bridge resistors R_3 and R_4 of the common branch, an emitter electrode connected in common with the emitter electrode of transistor Q_1 and a collector electrode connected in common with the emitter electrode of the output transistor Q_2.

Connected diagonally across the bridge **20** is an output circuit including an emitter coupled differential transistor amplifier A_2 feeding into the second relay K_2. The amplifier A_2 is of the same type as the amplifier A_1 and

operates in the same manner. Corresponding resistors of amplifier A_2 are given the same reference characteristics as for amplifier A_1. However, the output transistor Q_5 of the amplifier A_2 is connected through a voltage cut-down resistor **25** to the relay K_2 and the relay K_2 is wound to operate at a reduced voltage so it will have a faster operate time as later described. Both relays K_1 and K_2 are shunted by diodes *d* to limit induction transients through the relays.

The sensing cable S_4 has a negative temperature coefficient of resistance which follows nearly a straight line when the resistance is plotted to a logarithmic scale as is shown in FIGURE 3. A 50 foot length of such cable at a room temperature of 70° F. may have a resistance of 430,000 ohms which falls to 1760 ohms at an overheat temperature of 290° F. and to 100 ohms at a fire warning temperature of 400° F.

The bridge **10** is set to operate relay K_1 when any portion of the cable S_4 is subjected to a fire warning temperature, and the bridge **20** is set to operate the relay K_2 only if a short circuit develops between the center wire **16** or end terminals to the sheath **15**, a "short circuit" being herein considered to be 40 ohms or less. Further in accordance with the invention the relay K_1 is slugged by providing it with a shorted turn, indicated at **26**, so as to delay its operation and the relay K_2 is wound so as to lessen its inductance and resistance and reduce its operate voltage. The series resistor **25** is added so that both relays will operate at the same supply voltage from the respective amplifiers. The effect however of so reducing the operate voltage for the relay K_2 is to lower its inductance to resistance ratio to give the relay a faster response. Thus, the relay K_1 may have a delayed operate time of the order of 15 milliseconds and the relay K_2 an operate time of only 5 milliseconds, both as typical values. The sensing cable S_4 may on the other hand have a relatively slow response due to the thermal time lag inherent in a cable's construction. For instance, when the cable is suddenly subjected to a fire temperature there may be a delay of as much as 400 milliseconds in the response of the cable going from a resistance value at overheat temperature to its resistance value at a fire warning temperature. Since the relays have a relatively fast response the first and second bridges will be operated in sequence as the cable is heated to an elevated temperature, but if the cable is shorted its response is instantaneous and will cause the second bridge circuit to operate the relay K_2 first because of the relative delay in the response of the relay K_1. Stated in a more specific way, the invention comprehends delaying the first relay relative to the second relay by an operate time which is substantially less than the time required for the resistance of the cable to go from the resistance at which the first bridge circuit is set to operate to the resistance at which the second bridge circuit is set to operate when the cable is heated to an elevated temperature.

As typical values, each of the bridge resistors R_1, R_3, and R_5 may have a value of 2000 ohms; reference resistor R_2, 500 ohms; reference resistor R_6, 440 ohms; and resistor R_4 of the common branch, 400 ohms. Thus the bridge **10** will pass through a balance point when the resistance of the sensing cable S_4 falls below 100 ohms, and the bridge **20** will pass through a balance point when the sensing cable resistance falls below 40 ohms. In the amplifiers A_1 and A_2, resistor **21** may be 3300 ohms, resistor **24** may be 27 ohms and resistor **22** may be 2200 ohms. Further, resistor **25** may have 1000 ohms, relay K_1 may have 2400 ohms and relay K_2 may have 1000 ohms.

At resistances of sensing cable S_4 above 100 ohms, both bridges are unbalanced in a negative direction causing base Q_1 to be negative to base Q_3 and base Q_4 to be negative to base Q_6. These are non-conducting states giving no alarm. As the sensing cable resistance falls below 100 ohms, the polarity of bridge **10** is reversed to render the amplifier A_1 conducting to operate relay K_1, and as the sensing cable resistance falls below 40 ohms the polarity of bridge **20** is reversed to operate the relay K_2.

Since the difference between the operate time of relay K_1 and of relay K_2 is much less than the time required for the cable resistance to fall from 100 to 40 ohms responsive to a suddenly applied intense fire temperature the relay K_1 will operate first. This prior operation of relay K_1 has two effects: (1) it opens its *a* switch contacts to remove a ground connection from relay K_2 whereby to disable this relay, and (2) it operates its *b* switch contacts to disable a ground alarm circuit **26** and to close a fire alarm circuit **27**. By this closing of the fire alarm circuit a fire alarm device **28** such as a lamp or other suitable alarm device is operated. A continued drop of the sensing cable resistance after the bridge **10** is operated has no effect because the operation of the bridge **10** has disabled the relay K_2 connected to the second bridge **20**.

On the other hand, if the sensing cable S_4 is suddenly short circuited the resistance of the sensing cable S_4 falls through the operate points for the bridge **10** and bridge **20** at the same time, causing the relay K_2 to be operated first because of the delay in the operate time of the relay K_1. A prior operation of the relay K_2 opens its *a* contacts to remove a ground connection for the relay K_1 whereby to disable this relay and it closes its *b* contacts to complete the ground alarm circuit **26** (since relay K_1 is not operated) whereby to activate a ground alarm device **29** to indicate that a short circuit has occurred.

In the embodiment of the invention shown in FIGURE 2, the bridges and output amplifiers have the same arrangement as in the embodiment of FIGURE 1 but those components with different values are given the same reference character with a suffix letter *a*. As typical values bridge resistors R_{1a}, R_{3a} and R_{5a} may each have 3000 ohms; resistors R_{2a}, 1960 ohms, R_{4a}, 200 ohms and R_{6a}, 300 ohms; resistor **21**, 3300 ohms; resistor **24**, 27 ohms; emitter resistor 22_a of amplifier **10***a*, 7500 ohms; emitter resistor 22_{ab} of amplifier **20***a*, 1200 ohms; resistor **25**, 1000 ohms; resistance of relay K_1, 2400 ohms; resistance of relay K_2, 1000 ohms. The bridge **10***a* balances to operate the relay K_1 when the sensing cable is at an overheat temperature herein considered to be 290° F. (1760 ohms), and the bridge **20***a* balances to operate the relay K_2 when the sensing cable is at a fire warning temperature of 400° F. (100 ohms). The relay K_1 is again slugged to have an operate time of about 15 milliseconds and the relay K_2 is wound with a reduced inductance to have a fast operate time of about only 5 milliseconds, the same as in the embodiment of FIGURE 1. Also, the sensing cable S4 may again have a relatively slow response as before described.

Upon subjecting the sensing cable S4 to an overheat temperature the relay K_1 will be actuated. Operation of this relay closes its *c* contacts to provide a lock-in connection of the relay to ground **29**, and it closes its *d* contacts to complete an alarm circuit **30** whereby to activate an overheat warning device **31** and to prepare an alarm circuit **32** for a fire warning device **33**. The prior operation of the relay K_1 has however no effect on the operation of the relay K_2. As the sensing cable S4 is heated further to a fire warning temperature the bridge **20***a* will operate the relay K_2 to open its *c* contacts without any effect and to close its *d* contacts to activate the fire warning device **33**. Thus, upon heating the sensing cable through the overheat and fire operate points the overheat and fire warning devices are operated in sequence. As the cable cools down this process is reversed to return the system to normal.

On the other hand, if a short suddenly develops in the sensing cable S_4 the cable passes through the overheat and

fire warning points simultaneously causing the relay K_2 to operate first because of its faster response. As the relay K_2 is operated its *c* contact is opened to break a circuit 34 to ground 35 for the relay K_1 whereby to disable this relay, and its *d* contact is closed in fire alarm circuit 32 but without effect because the relay K_1 has not been operated to prepare this circuit for operaiton. Thus, a short condition is ineffective to give any alarm.

Integrity of the system shown in FIGURE 2 can however be checked when the system is in either a normal standby condition of in overheat condition (but not in a fire warning condition) by pressing a test switch 36 to connect the battery B to a test relay K_3 having a ground connection completed through *c* contacts of the relay K_2 to ground 35. Operation of the test relay opens its *a* contacts to break the loop connection between the end terminals of the sensing cable S_4 and connects the far end of the center wire of the cable to ground 37, and it closes its *b* contact to supply a lock-in connection to ground 35 for the test relay as well as to supply ground to the relay K_1 independently of the relay K_2. The grounding of the far end of the center wire of the sensing cable S_4 tests the cable for continuity; for example, if the center wire is continuous the grounding of the far end will operate both relays K_1 and K_2 to provide both overheat and fire warnings when the system is in normal standby condition and to provide a fire warning when the system is already in an overheat condition. When the test switch is released the test relay drops out to return the system to normal.

The embodiments of my invention herein particularly shown and described are intended to be illustrative and not necessary limitative of my invention since the same are subject to changes and modifications without departure from the scope of my invention, which I endeavor to express according to the following claims.

I claim:

1. A fire detection system including a negative temperature coefficient resistor device for sensing fire conditions, said sensing device being characterized as having a thermal time delay in its response, first and second Wheatstone bridges have a common branch, said sensing device being connected in an arm of said common branch, respective diagonal output circuits connected to said bridges each including an output relay, said first bridge being pre-set in a state of unbalance to operate its respective relay when the resistance of said sensor device falls to a first predetermined value, said second bridge being pre-set in a greater state of unbalance to cause its respective relay to be operated when the resistance of said sensing device falls to a second resistance value substantially lower than said first value, means for delaying said first relay relative to said second relay by an operate time which is substantially less than the response time of said sensing device in falling from said first to said second resistance values responsive to the sensing device being subjected to an elevated temperature whereby upon exposure of said sensing device to a fire condition said first relay is the first to be operated but upon a short circuit developing in said sensing device said second relay is the first to be operated, an alarm circuit, and means controlled jointly by said relays for activating said alarm circuit.

2. The fire detection system set forth in claim 1 including means operated by said second relay when the second relay is the first to operate for disabling said first relay.

3. The fire detection system set forth in claim 2 wherein said alarm circuit is adapted to indicate a fault condition in said sensing device, including switches in said alarm circuit controlled respectively by said relays for activating said alarm circuit only when said first relay is not actuated and said second relay is actuated.

4. The fire detection system set forth in claim 2 wherein said alarm circuit is adapted to indicate a fire condition, including switches in said alarm circuit controlled respectively by said relays for activating said alarm circuit only when said first and second relays are actuated sequentially in the order herein named.

5. A fire detection system including a negative temperature coefficient resistor device for sensing fire conditions, said sensing device being characterized as having a thermal time delay in its response, first and second Wheatstone bridges have a common branch, said sensing device being connected in an arm of said common branch, respective diagonal output circuits connected to said bridges each including an output relay, said first bridge being pre-set in a state of unbalance to operate its respective relay when the resistance of said sensor device falls to a first predetermined value, said second bridge being pre-set in a greater state of unbalance to cause its respective relay to be operated when the resistance of said sensing device falls to a second resistance value substantially lower than said first value, means for delaying said first relay relative to said second relay by an operate time which is substantially less than the response time of said sensing device in falling from said first to said second resistance values responsive to the sensing device being subjected to an elevated temperature whereby upon exposure of said sensing device to a fire condition said first relay is the first to be operated but upon a short circuit developing in said sensing device said second relay is the first to be operated, a fire alarm circuit serially including normally open switch contacts of both said relays whereby both relays must be operated to provide an alarm, and means controlled by said second relay for opening the circuit of said first relay to prevent operation of the first relay when the second relay is the first operated.

6. The fire alarm system set forth in claim 5 wherein said first bridge is set to operate when said sensing device is exposed to an overheat condition, and wherein said second bridge is set to operate when said sensing device is exposed to a fire condition.

7. A fire detection system including a negative temperature coefficient resistance cable for detecting a fire condition, said detecting cable being characterized as having a thermal time delay in its response, first and second Wheatstone bridges having a common branch, said first bridge being set to operate at a fire temperature and said second bridge being set to operate at above fire temperature so that only the first bridge is operated when said detecting cable is exposed to a fire condition, means for delaying said first bridge with respect to said second bridge to cause said second bridge to operate first when said detecting cable is shorted, a fire alarm circuit, a fault alarm circuit, switch means in said alarm circuits to cause said fire alarm circuits to be activated when said first relay is operated and said fault alarm circuit to be activated when only said second relay is operated, and switch means controlled by said relays whereby operation of either relay prevents the other from being operated.

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