

Nov. 10, 1964

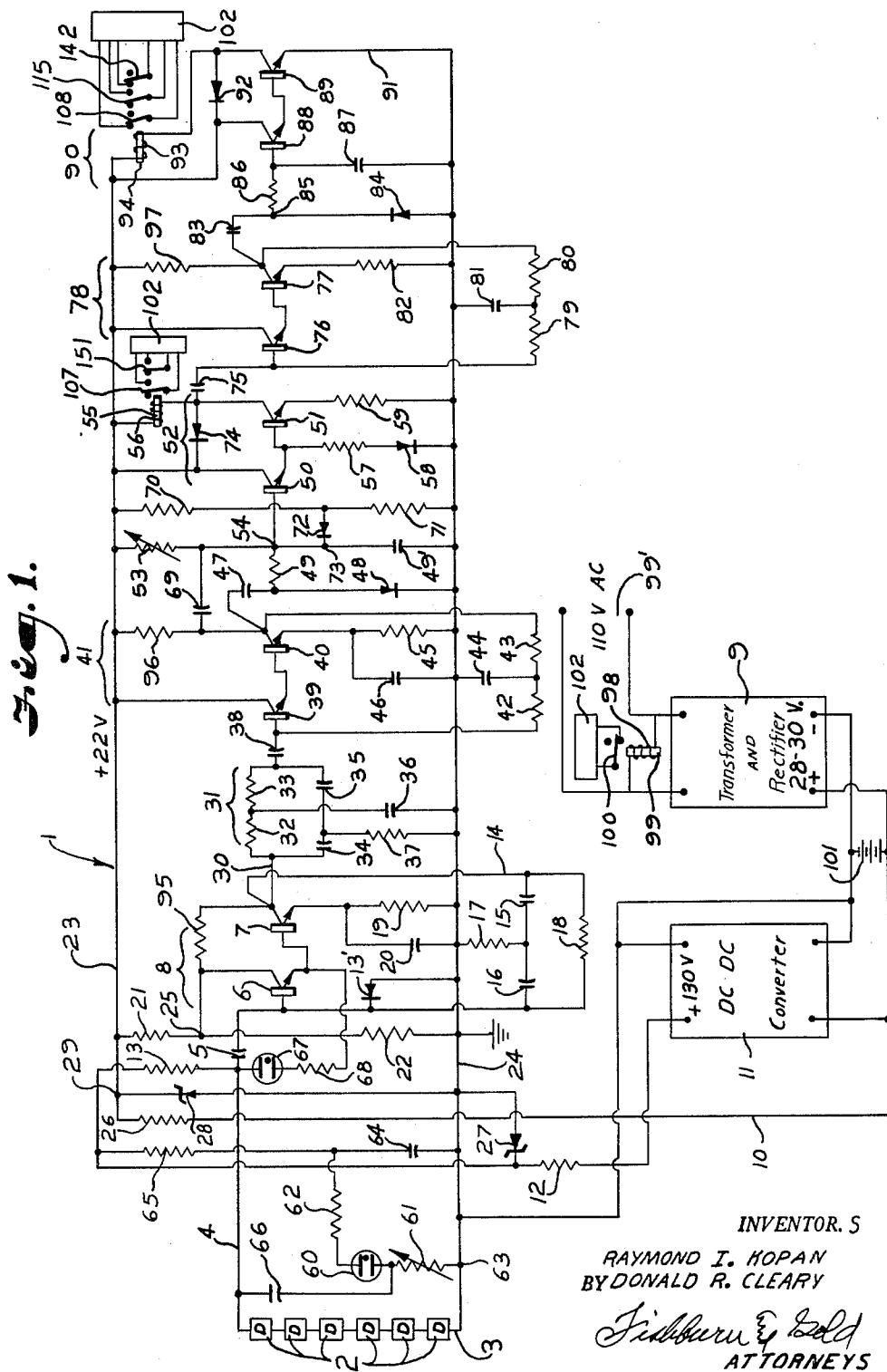
R. I. KOPAN ETAL

3,156,908

FLAME RESPONSIVE APPARATUS

Filed Dec. 4, 1961

2 Sheets-Sheet 1



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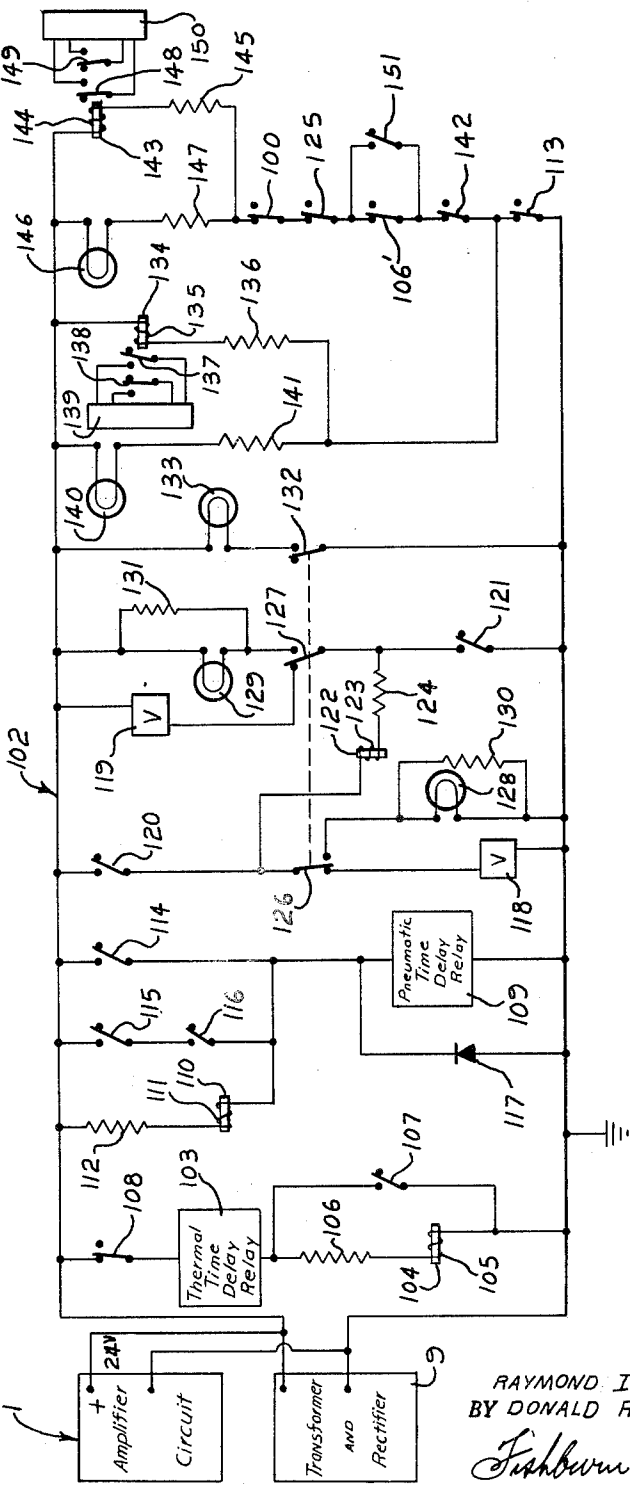
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2 Sheets-Sheet 2

Fig. 2.



INVENTOR. S
RAYMOND I. KOPAN
BY DONALD R. CLEARY
Fishburne & Gold
ATTORNEYS

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FLAME RESPONSIVE APPARATUS

Raymond I. Kopan, Prairie Village, Kans., and Donald R. Cleary, Kansas City, Mo., assignors, by mesne assignments, to Viking Corporation, Hastings, Mich., a corporation of Michigan

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12 Claims. (Cl. 340-228)

This invention relates to apparatus for detecting and signalling fires, and more particularly to improved electrical or electronic systems for the detection of fire flame which offers extremely high reliability and operability monitoring coupled with low power consumption.

Heretofore systems have been developed which include infrared sensitive cells in combination with an amplifier unit containing vacuum tubes and adapted to signal a warning and/or actuate an extinguishing device due to the presence of flame. These systems operate on the principal that modulated infrared radiant energy in the lower audio or sub-audio frequency range is a unique property of fire flame and thus can be used to indicate the presence of an unwanted fire without resorting to the detection of secondary fire effects, for example, smoke or increased thermal level. Certain systems of this type have included self-monitoring features whereby critical components such as amplifier elements and transformer windings are continually checked for operability by passing signals therethrough which do not trigger a fire alarm. Such self-monitoring, however, due to the use of a monitoring signal of a different fundamental frequency than a fire signal and the particular electronic circuitry configuration permits several situations to arise wherein the fire detecting apparatus is actually non-functional but, such condition is not clearly indicated. Existing apparatus of this type, upon the elimination of fire flame, either requires manual turn-off of the fire extinguishing system or automatically turns the extinguishing system off while smouldering still exists. In addition, such apparatus usually requires a large supply of stand-by power for continuous operation in case the normal power source is interrupted for example, by the fire. The standby systems, for example, may be engine driven generators or large storage batteries coupled with motor-generator current conversion sets. In both instances, large capital outlays and continuous substantial maintenance expenses are required while not offering the desired reliability.

It is the principal objects of the present invention to provide an integrated fire detection system with increased reliability than has heretofore been available; to provide a fire detection and alarm apparatus which is self-monitored by means of a signal having a frequency within the range of the fundamental frequencies radiated by flames whereby a positive check of system operability is obtained; to provide such fire detecting apparatus which is operable to turn off the sprinkler system a predetermined time period after flame signals are no longer received whereby the combustible materials are cooled to the point where a rekindling of the fire is highly unlikely; to provide such apparatus wherein reliable signal integration is provided for better protection against a false alarm caused by transient flames such as the striking of a match; to provide such a fire detecting device which is operable during periods of normal or commercial power failure from a relatively small battery power supply due to the elimination of conventional high power drawing vacuum tubes; to provide such a fire monitoring circuit which is adapted to maintain a sprinkler system or the like in operation should the fire damage the detector circuit or amplifier components during fire operation; to provide such a system which requires extremely low standby power; to provide such a device which includes means

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for testing the operability of the system without actually actuating the valves of a sprinkler system or the like; and to provide such a fire monitoring apparatus which is designed for extremely long life with little maintenance.

Other objects and advantages of this invention will become apparent from the following description taken in connection with the accompanying drawings wherein are set forth by way of illustration and example certain embodiments of this invention.

FIGURE 1 is a schematic wiring diagram of a fire signal amplifier circuit embodying this invention and including the amplifier monitoring components.

FIGURE 2 is a schematic diagram of a control relay circuit embodying this invention and including monitoring components therefor.

Referring to the drawings in more detail:

Detector Signal Amplifier

The reference numeral 1 indicates generally a fire detector amplifier circuit. The circuit 1 includes a plurality of physically spaced, series interconnected, photo-resistive lead-sulfide detectors or cells 2 adapted to provide a fluctuating resistance in response to low audio and sub-audio frequency fluctuating infrared radiation impinging thereon, for example, in the range of about three to thirty cycles per second. The number of series connected cells 2 can be varied up to approximately fifteen without major modification of the circuit. The cells 2 are preferably disposed within a building or the like and respectively located in particular areas where unwanted fires are most likely to occur.

The cells 2 are connected between ground potential at 3 and a lead 4 which is coupled through a capacitor 5 to the base of a transistor 6. The transistor 6 is interconnected with a transistor 7 to form a first compound connected transistor A.C. amplifier stage generally indicated at 8. A suitable transformer and rectifier circuit 9 receives commercial power, for example 110 volts A.C. and converts same to plus 28-30 volts D.C. which is impressed on a line 10. A suitable D.C.-D.C. converter 11 converts a portion of the transformer and rectifier 9 output to a higher voltage proportionate to the number of cells 2, in the illustrated example, plus 130 volts D.C. which is directed through series connected current limiting resistors 12 and 13 to the lead 4 for impressing positive relatively high voltage potential across the cells 2. It will be appreciated that a flickering flame produces an alternating voltage at the input of the first A.C. amplifier stage 8 because of the corresponding resistance change appearing across the infrared sensitive cells 2. A grounded reversed biased diode 13' is connected in series with the coupling capacitor 5 to prevent degenerative back voltage forming a portion of large signals developed by the cells 2 from being impressed on the input of the amplifier stage 8 which might otherwise cause damage thereto. The amplifier stage 8 includes a feedback loop generally indicated at 14 and comprising capacitors 15, 16 and resistors 17 which form a high pass filter to render the amplifier stage 8 particularly sensitive to the low audio and sub-audio frequency range. In order to obtain a stable operating point for the amplifier stage 8, the base of the transistor 6 is connected to the collector of the transistor 7 through an external biasing resistor 18 whereby a variation in collector characteristics will cause a corresponding change in bias voltage which re-establishes the desired operating point. Additional stability for the amplifier stage 8 is obtained by the use of an emitter swamping resistor 19. A bypass capacitor 20 prevents a degenerative feedback of the A.C. signal which may otherwise be developed across the resistor 19.

Transistor noise which increases as frequency decreases is reduced by lowering the collector voltage of the am-

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plifier stage 8 through a voltage dividing network comprising resistors 21 and 22 connected in series between a positive low voltage D.C. bus or supply line 23 and ground 24 with the collector supply tap therebetween at 25. A current limiting resistor 26 normally reduces the low voltage D.C. supply at the line 23 to plus 22 volts. A Zener diode 27 is tapped between the resistors 12 and 13 and ground 24 to regulate the high voltage output of the D.C.-D.C. converter 11 and particularly to attenuate switching transients from relays described hereinafter which would otherwise interfere with the amplifier operation. The low voltage bus or line 23 is regulated with a Zener diode 28 connected between a terminal 29 thereon and ground 24.

The output of the amplifier stage 8 is connected through a line 30 to a twin-T notch filter 31 comprising series connected resistors 32 and 33 in parallel with series connected capacitors 34 and 35, grounded A.C. shunt capacitor 36 tapped between the resistors 32 and 33 and a grounded resistor 37 tapped between the capacitors 34 and 35. The notch filter 31 is particularly tuned to attenuate 60 c.p.s. noise forming a portion of the amplifier stage 8 output. The filtered signal is then coupled through a capacitor 38 to the base of a transistor 39 which forms, with a transistor 40, a second compound connected transistor A.C. amplifier stage 41. Series connected resistors 42 and 43 provide self-biasing for the amplifier stage 41 to obtain a stable operating point. A grounded capacitor 44 is tapped between the resistors 42 and 43 to reduce the A.C. degenerative feedback caused by self-biasing. An emitter swamping resistor 45 provides additional stability and a bypass capacitor 46 around the resistor 45 prevents degenerative A.C. feedback of the A.C. signal otherwise appearing across the resistor 45.

A portion of the output signal from the amplifier stage 41 is coupled through a capacitor 47 which is connected in series with a grounded forward biased diode 48 whereby the signal is converted to a pulsating negative D.C. The pulsating negative signal below the capacitor 47 is low pass filtered with a current limiting resistor 40 and capacitor 49' and directed to the base of a transistor 50 which is interconnected with a transistor 51 to form a compound connected transistor D.C. amplifier stage 52. The amplifier stage 52 is adapted to provide increased output current in response to an increased positive input bias. An adjustable positive bias for the input of the amplifier stage 52 is provided through a variable resistor 53 connected at one end thereof to the low voltage bus or line 23 and at the other end thereof between the resistor 49 and the base of the transistor 50 at 54. By means of the variable resistor 53, a selected positive bias is impressed on the input of the amplifier stage 52 in opposition to the D.C. negative potential supplied through the resistor 49. A fire signal relay 55 has the coil 56 thereof normally energized by the output of the amplifier stage 52 acting in response to the positive bias on the input thereof occurring in the absence of sufficient negative signal from the amplifier stage 41. When sufficient output signal from the amplifier stage 41 is obtained, the fire signal relay 55 is de-energized to initiate a sequence of events described hereinafter.

The self-biasing technique and the use of emitter swamping resistors, as noted above with reference to the A.C. amplifier stages 8 and 41 provide good temperature compensation over a wide operating temperature range. However, the use of self-biasing and a large swamping resistor on the D.C. amplifying stage 52 does not give good temperature compensation. As the temperature increases, the base to emitter resistance of the transistors 50 and 51 decreases and results in an increase in the base current and therefore, the collector current. Conversely, when the temperature decreases, the base to emitter resistance increases and causes a decrease in the collector current. Therefore, a low temperature would tend to decrease the current in the coil 56 to a point where a

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false alarm may be initiated. To compensate for this temperature effect, a resistor 57 is placed in series with a forward biased silicon diode 58 and the combination is connected between the emitter of the transistor 50 and ground. This gives adequate temperature compensation by automatically decreasing the bias voltage as the temperature goes up and increasing the bias voltage as the temperature goes down. An emitter swamping resistor 59 is connected between the emitter of the transistor 51 and ground.

Circuit Monitoring Network

A circuit monitoring network for constantly checking the operability of the fire detector amplifier circuit includes a neon bulb 60 series connected between a variable resistor 61 and a resistor 62. The resistor 61 is grounded at 63. The resistor 62 is tapped between a grounded capacitor 64 and a current limiting resistor 65 which is connected between the resistors 12 and 13 on the high voltage input. The neon bulb 60, cooperating with the resistors 61, 62 and the capacitor 64, forms a neon bulb relaxation oscillator circuit adapted to impress a low frequency monitor signal onto the bias of the cells 2 of insufficient magnitude but within the correct frequency range to de-energize the fire signal relay 55, for example, 15 to 20 c.p.s. A coupling capacitor 66 connects the output of the neon bulb relaxation oscillator to the line 4. A predetermined decrease in resistance across the cells 2, for example, due to a detector circuit short, will shunt the monitor pulse to ground through the cell so that it no longer appears across the trouble signal relay (described hereinafter) and causes a trouble alarm. A monitoring circuit for indicating excessively increased resistance across the cells 2 comprises a neon bulb 67 having one side thereof connected to the high voltage lead 4 and the other side in series with a resistor 68 communicating with the emitter-base connection of the amplifier stage 8. A predetermined increase in the resistance across the cells 2, for example, caused by the opening of a cell increases the potential across the neon bulb 67 due to a voltage dividing action between the resistor 13 and the cells or detectors 2. This potential increase causes the neon bulb 67 to fire permitting current to flow through the transistor 7 and the resistor 19 to ground, whereby the transistor 7 is biased to saturation. Saturating the transistor 7 kills the gain of the amplifier stage 8 and thus prevents the monitor signal from passing through the remainder of the circuit causing the de-energizing of the trouble signal relay (described hereinafter).

The monitor signal generated by the neon bulb 60 is normally amplified by the amplifier stage 8, passes through the filter 31 and is further amplified by the amplifier stage 41. Due to D.C. conversion by the diode 48 and filtering by resistor 49 and capacitor 49' the monitor signal is difficult to pass through the resistor 49 to the amplifier stage 52. Therefore, a portion of the output signal from the amplifier stage 41 is coupled through a capacitor 69 directly to the input of the amplifier stage 52, bypassing the rectifying and filtering circuits.

A fire signal from the cells 2 drives the D.C. amplifier stage 52 toward cutoff. However, if this stage were allowed to reach cutoff the A.C. gain thereof would be zero and under such conditions, the monitor signal would be blocked from reaching the trouble signal relay (described hereinafter), causing a false trouble alarm. In order to overcome this problem, a clamping circuit comprising voltage dividing resistors 70 and 71 are connected between the bus line 23 and ground. A diode 72 is tapped between the resistors 70 and 71 and forward biased to a terminal 73 located between the resistor 49 and the filtering capacitor 49'. When the bias voltage across the capacitor 49' reaches a slightly lower magnitude than across the resistor 71, the diode 72 starts to conduct and "clamps" the capacitor 49' to the voltage across the re-

sistor 71. The amplifier stage 52 is thus not permitted to go completely to cut-off and sufficient A.C. gain is retained to transmit the monitor signal therethrough.

A diode 74 is connected between the respective collectors of the transistors 50 and 51 to provide a shorted path for the reversed polarity transient developed across the relay coil 56 upon de-energizing. A coupling capacitor 75 is connected between the collector of the transistor 51 and the base of a transistor 76 which forms, with a transistor 77, a third A.C. amplifier stage 78 adapted to amplify the monitor signal developed across the capacitor 75. Series connected resistors 79 and 80 provide self-biasing for the amplifier stage 78 to obtain a stable operating point. A grounded capacitor 81 is tapped between the resistors 79 and 80 to reduce the A.C. degenerative feedback caused by the self-biasing. An emitter swamping resistor 82 provides additional operating point stability to the amplifier stage 78.

A coupling capacitor 83 connects the output of the amplifier stage 78 to a grounded reverse-biased diode 84 adapted to rectify the signal. A terminal 85 is located intermediate the coupling capacitor 83 and diode 84, and a resistor 86 is connected thereto. The other end of the resistor 86 is connected to a grounded capacitor 87 to form a low pass filter circuit for the D.C. pulsating signal developed at the terminal 85.

The base of a transistor 88 is tapped between the resistor 86 and capacitor 87 and forms, with a transistor 89, a second D.C. compound connected transistor amplifier stage 90. The emitter of the transistor 89 is connected to ground through a lead 91. A diode 92 offers a shorting path for reversed polarity transients developed across the coil 93 of a trouble signal relay 94 constituting the output load of the amplifier stage 90.

Resistors 95, 96 and 97 are respectively connected between the common collectors of the A.C. amplifier stages 8, 41 and 78 to provide output loads for obtaining the output signals thereof.

The coil 98 of a relay 99 is connected across the 110 volt A.C. supply 99', maintaining a normally energized condition thereof and holding a set of contacts 100 closed for monitoring the availability of commercial power for the amplifier circuit in a manner disclosed hereinafter. A suitable battery 101 provides standby 24 volt D.C. potential for emergency use in case of commercial power failure.

In order to detect component failure in the amplifier circuit, an A.C. signal not large enough to produce the de-energizing or drop-out of the fire signal relay 55 is passed through the entire circuit. Upon reaching the output of the amplifier stage 52 (which feeds the fire signal relay 55), the monitor signal is further amplified by the amplifier stage 78 and changed to a positive D.C. voltage for biasing the amplifier stage 90 into saturation, energizing the normally energized trouble signal relay 94. If any component fails which interrupts the monitor signal or materially decreases the A.C. gain through the entire amplifier, the normally energized trouble signal relay 94 will drop out and initiate a trouble alarm, as described hereinafter.

A transistor when used as a common emitter for voltage amplification has a low input impedance, but the cells 2 are high impedance devices and must be coupled into a high impedance or severe signal attenuation will result. Coupling between amplifier stages also presents a problem because of the high reactance of a practically sized coupling capacitor at the low frequencies. In order to prevent severe attenuation of the signal between the cells and the amplifier input and also between the respective amplifier stages, the transistors, as noted above, are compound connected in pairs per stage with the common collector input for each amplifier stage directly coupled to the common emitter. In this manner, one transistor in each stage provides the required high input impedance,

while the other provides the necessary signal amplification.

Control Circuit

FIGURE 2 schematically illustrates a control circuit generally indicated at 102 which embodies additional features of this invention. The operation of the control circuit 102 is generally initiated by the condition of the fire signal relay 55 and the trouble signal relay 94 which are the final operating units in the amplifier circuit schematically illustrated in FIGURE 1.

A time delay relay 103 is preferably of the thermal type wherein a filament (not shown) or the like is heated by current passing therethrough. The filament heats a bi-metal switch or the like, (not shown) and causes same to complete a circuit through the relay after a delay period, for example, of from 5 to 180 seconds. A normally energized monitor relay 104 has the coil 105 thereof connected in series with a current limiting resistor 106 and the power input of the thermal time delay relay 103. The monitor relay 104 and resistor 106 draw an insufficient current to cause an actuation of the thermal time delay relay 103 but continually monitor the continuity thereof so as to demonstrate present operability. The normally energized condition of the monitor relay 104 maintains a set of contacts 106' in a closed condition, the contacts 106' opening when current to the monitor relay 104 is interrupted.

The fire signal relay 55 has a set of contacts 107 thereon which is maintained in a normally open position during the normal or stand-by period in which the fire signal relay 55 is energized. The contacts 107 are adapted to bypass the monitor relay 104 to provide a high current path for energizing the thermal time delay relay 103 upon de-energizing the fire signal relay 55.

The trouble signal relay 94 has a set of contacts 108 thereon which is maintained in a closed position during the normal period of relay energization. The set of contacts 108 is connected in series with the power input of the thermal time delay relay 103 for de-energizing the relay 103 when the trouble signal relay 94 is de-energized. The set of contacts 108 is adapted to prevent a fire alarm or operation, described more fully hereinafter, if trouble has occurred in the fire signal amplifier circuit prior to the time the delay period has elapsed in the thermal time delay relay 103. This circuitry is used to anticipate the possibility that a failure of certain components in the amplifier circuit may result in the de-energizing of both the fire signal relay 55 and trouble signal relay 94.

A time delay relay 109 is preferably of the pneumatic type which is adapted to close a plurality of normally open sets of contacts instantaneously upon the energizing thereof and open said contacts after a preset time delay occurring after the de-energizing thereof. A second normally energized monitor relay 110 has the coil 111 thereof connected in series with a current limiting resistor 112 and the power input of the time delay relay 109. Sufficient current passes through the resistor 112 and relay 110 to monitor the continuity of the time delay relay 109, but this current is insufficient in amount to cause an actuation thereof. The normally energized condition of the relay 110 maintains a set of contacts 113 in a closed condition, said contacts 113 opening in case of current interruption to the monitor relay 110, for example caused by an opening of the time delay relay 109.

The thermal time delay relay 103 has a normally open set of contacts 114 thereon adapted to bypass the monitor relay 110 and energize the pneumatic time delay relay 109 upon the completion of the thermal time delay relay cycle. The trouble signal relay 94 has a second set of contacts 115 thereon which is maintained in an open condition when the trouble signal relay 94 is energized. The contacts 115 are positioned in the control circuit 102 for bypassing the thermal time delay relay contacts 114 to permit a sealing or locking-on of the pneumatic time delay relay 109 in the event that the

trouble signal relay 109 is energized, for example, by fire damage to the amplifier circuit. The time delay relay 109 has a set of contacts 115 thereon which is adapted to close instantaneously with the energizing of the relay 109. The set of contacts 116 is thus in a position to cooperate with the normally open trouble signal relay contacts 115 to seal or lock-on the pneumatic time delay relay 109. A diode or rectifier 117 is connected into the circuit so as to bypass the pneumatic time delay relay 109, but is biased in a direction whereby current does not normally flow therethrough. Upon the deactuation of the pneumatic time delay relay 109, high voltage transients of opposite polarity are set up which are harmlessly shorted out through the diode 117 rather than producing a possible interference with circuit or apparatus operation.

A pair of fire extinguishing flow solenoid valves 118 and 119 are respectively adapted to control the flow of a fire extinguishing liquid, for example, water in a fire control sprinkler system (not shown). The solenoid valves 118 and 119 permit flow only when energized. A set of contacts 120 and a set of contacts 121 are connected in series respectively with the valves 118 and 119. The sets of contacts 120 and 121 form portions of the pneumatic time delay relay 109 and, as noted, are adapted to close when the time delay relay 109 is actuated and open after the completion of a pre-set time delay beginning after the de-energizing of the time delay relay 109. Thus, the solenoid valves 118 and 119 are adapted to remain energized for a pre-set period, for example ten to fifteen minutes, after the cells 2 have signaled that the flames have been extinguished to cool the combustible materials. The cells 2 signal that the flames are extinguished by re-energizing the fire signal relay 55 which reopens the set of contacts 107 for de-actuating the thermal time delay relay 103 and thereby opening the set of contacts 114.

A third monitor relay 122 has the coil 123 thereof series connected between the solenoid valves 118 and 119 and a current limiting resistor 124 for monitoring electrical continuity through the solenoid valves 118 and 119 without permitting enough current to flow therethrough to cause the actuation thereof. The relay 122 has a set of contacts 125 thereon which is normally maintained in a closed condition due to the current flow through the relay 122, but is adapted to open upon an interruption of the current through the relay 122. A pair of single pole double throw switches 126 and 127 are adapted to be hand actuated and collectively complete the respective circuits to the solenoid valves 118 and 119. During periods of servicing when it is desired to check the operability of the fire detecting apparatus without actually permitting flow through the solenoid valves 118 and 119, the switches 126 and 127 are actuated for directing current flow through respective pilot lights 128 and 129 and respective resistors 130 and 131 to substitute the same load in the circuit which would otherwise be drawn by the solenoid valves 118 and 119. The pilot lights 128 and 129 provide a visual indication of satisfactory operation under test conditions.

The solenoid valves 118 and 119 are connected in parallel to increase the reliability of the valve operation since it is contemplated that either the valve 118 or the valve 119 are of sufficient capacity to completely actuate the sprinkler system (not shown).

The switches 126 and 127 are mechanically interconnected whereby they operate simultaneously with a switch 132. The switch 132 is connected in series with a pilot light 133. The pilot light 133 thus indicates when the switches 126 and 127 are in test position and also presents a warning signal to the effect that the system cannot operate the solenoid valves while the switches 126 and 127 are maintained in the test position.

A normally energized auxiliary fire signal relay 134 has the coil 135 thereof connected in series with a current

limiting resistor 136 which is connected through the contacts 113 of the monitor relay 110 to ground. When the thermal time delay relay 103 closes the set of contacts 114 to actuate the pneumatic time delay relay 109, the monitor relay 110 is bypassed and thus de-energized, opening the set of contacts 113 and de-actuating the auxiliary fire signal relay 134. The de-actuation of the auxiliary fire signal relay 134 causes normally open sets of contacts 137 and 138 to close energizing auxiliary equipment 139, for example, audible warning alarms, a fire department signalling device and/or a police department signalling device. A pilot light 140 in series with a current limiting resistor 141 is connected in parallel with the monitor relay 134 and resistor 136 whereby a visual indication of a fire condition is provided.

The trouble signal relay 94 has a third set of contacts 142 thereon maintained in the closed position while the trouble signal relay 94 is in an energized condition. An auxiliary trouble signal relay 143 has the coil 144 thereof connected in series with a current limiting resistor 145 and the sets of contacts 100, 125, 106', 142 and 113. The auxiliary trouble signal relay 143 is normally maintained in the energized condition, however, it is apparent that the opening of any one of the sets of contacts 100, 125, 106', 142 or 113 will de-energize the relay. A pilot light 146 is connected in series with a current limiting resistor 147 and the combination connected in parallel with the auxiliary trouble signal relay 143 and resistor 145, whereby the de-energizing of the relay 143 will be accompanied by the extinguishing of the pilot light 146. Sets of contacts 148 and 149 are maintained in the open condition while the auxiliary trouble signal relay 143 is energized, however, upon the de-energizing thereof the sets of contacts 148 and 149 close to initiate the actuation of auxiliary equipment, such as an audible alarm 150 to signal a malfunction in the fire monitoring apparatus.

The fire signal relay 55 has a normally open second set of contacts 151 thereon which is adapted to bypass the set of contacts 106' on the first monitor relay 104. If a transient signal momentarily causes the fire signal relay 55 to de-energize so as to bypass the relay 104 and open the set of contacts 106', the auxiliary trouble signal relay 143 will remain energized so as not to initiate a false momentary trouble signal alarm.

The thermal time delay relay 103, in addition to preventing a fire alarm during transient signal conditions such as the striking of a match or the sudden entrance of daylight through a doorway or the like, provides integration of intermittent signals from marginal fires. During marginal fire conditions, an intermittent signal is received from the fire which must be integrated until sufficient energy is obtained to actuate the thermal time delay relay 103. Under such conditions, the normal delay time thereof will be extended. It is noted that during fire conditions the monitor relay 110 will be deenergized opening the set of contacts 113 and de-energizing the auxiliary trouble signal relay 143 and pilot light 146, in a sense providing a secondary fire signal should other fire signal circuits fail. The auxiliary trouble signal relay 143 will be automatically energized upon the loss of a fire signal if the system is working properly. It is also noted that the entire system, where practicable maintains relays in a normally energized condition to provide a fail-safe feature.

Fire Operation

In operation, a flickering flame produces an alternating voltage across one or more of the cells 2 due to the resistance change of the infrared sensitive detectors. The signal is amplified through two A.C. and one D.C. amplifier stages causing the fire signal relay 55 to drop out from its normally energized state. The relay 55 energizes the thermal time delay relay 103 which provides a signal integrating delay. After the initial delay, the pneumatic time delay relay 109 is actuated which in turn instantaneously energizes the solenoid valves 118 and 119, for

example, to turn on a sprinkler system (not shown). When the flame ceases to exist, all relays return to their normal energized condition, except the pneumatic time delay relay 109 which continues the actuation of the solenoid valves 118 and 119 for a predetermined period to insure the cooling of the combustible materials.

It is to be understood that while we have illustrated and described one form of our invention it is not to be limited to the specific form or arrangement of parts herein described and shown except insofar as such limitations are included in the claims.

What we claim and desire to secure by Letters Patent is:

1. In fire detecting apparatus of the type having photo-resistive cells adapted to provide a fluctuating signal in response to low frequency fluctuating infrared radiation impinging thereon, said signal being of a magnitude to induce a fire signal, a circuit monitoring network comprising, an oscillator adapted to continuously impress a low frequency monitor signal onto the cell output of smaller magnitude than said first named magnitude but within the correct frequency range to induce a fire signal, and means adapted to produce a signal in response to the interruption of monitor signal transmission through said apparatus.

2. In fire detecting apparatus of the type having photo-resistive cells adapted to provide a fluctuating signal in response to low frequency fluctuating infrared radiation impinging thereon, an amplifier adapted to amplify the output of said cells, a circuit monitoring network comprising an oscillator adapted to impress a low frequency monitor signal onto the output of said cells, said monitor signal being connected to ground through said cells whereby an excessive decrease in resistance across said cells will attenuate said monitor signal, a cell resistance monitoring circuit connected between the output of said cells and said amplifier and adapted to conduct current with a predetermined increase in resistance across said cells, the conduction through said cell resistance monitoring circuit biasing said amplifier to saturation and destroying the gain thereof whereby the monitor signal is either blocked or attenuated respectively upon an excessive decrease or predetermined increase in the resistance thereof, and means adapted to produce a signal in response to the interruption or excessive attenuation of said monitor signal through said apparatus.

3. Fire detecting apparatus comprising, a photo-resistive cell adapted to provide a fluctuating signal in response to low frequency fluctuating infrared radiation impinging thereon, a first supply of D.C. voltage, said first supply of voltage being adapted to bias said cell, a first amplifier stage coupled to said cell whereby a fluctuating signal is developed at the input of said first amplifier stage in response to said fluctuating radiation, a rectifying circuit adapted to convert a portion of said signal to D.C., a D.C. amplifier stage adapted to provide increased output current in response to an increased input bias, said D.C. amplifier stage being adapted to receive said D.C. signal, a second supply of D.C. voltage, said second supply of voltage being of opposite polarity than said signal and adapted to impress a selected bias on the input of said D.C. amplifier stage in opposition to said D.C. signal, and a fire signal relay normally energized by the output of said D.C. amplifier stage acting in response to said bias on the input thereof, whereby said fire signal relay is de-energized when said D.C. signal becomes great enough to decrease said bias on the input of said D.C. amplifier stage a predetermined amount.

4. The apparatus of claim 3 including a trouble alarm circuit comprising, signal generating means adapted to impress a monitor signal onto the cell bias of smaller magnitude than said first named magnitude but within the correct frequency range to de-energize said first signal relay, and means responsive to the transmission of said monitor signal through said apparatus, said latter means being adapted to produce a signal in response to the interruption of monitor signal transmission or a predeter-

mined decrease in the strength of the transmitted monitor signal.

5. Fire detecting apparatus comprising, a plurality of spaced series interconnected photo-resistive cells adapted to provide a fluctuating resistance in response to low audio and sub-audio frequency fluctuating infrared radiation impinging thereon, a supply of positive relatively high voltage, said high voltage supply being adapted to bias said cells, a first compound connected transistor A.C. amplifier stage particularly sensitive to the low audio and sub-audio frequency range, said first A.C. amplifier stage being capacitively coupled to said cells whereby a fluctuating signal is developed at the input of said first A.C. amplifier stage in response to said fluctuating radiation, a second compound connected transistor A.C. amplifier stage, a filter network connected to the output of said first A.C. amplifier stage for attenuating noise in said signal, the output of said filter network being capacitively coupled to the input of said second A.C. amplifier stage, a rectifying circuit connected to the output of said second A.C. amplifier stage whereby a portion of the A.C. signal therefrom is converted to a D.C. signal of negative polarity, a compound connected transistor D.C. amplifier stage adapted to provide increased output current in response to an increased positive input bias, said D.C. amplifier stage being connected at the input thereof to said first rectifying circuit for receiving said D.C. negative signal, a supply of positive relatively low voltage, said low voltage supply being adapted to impress a selected positive bias on the input of said D.C. amplifier stage in opposition to said D.C. negative signal, and a fire signal relay normally energized by the output of said D.C. amplifier stage acting in response to said positive bias on the input thereof, whereby said fire signal relay is deenergized when said D.C. negative signal becomes great enough to decrease the positive bias on the input of said D.C. amplifier stage a predetermined amount.

6. Fire detecting apparatus comprising, a plurality of spaced series interconnected photo-resistive cells adapted to provide a fluctuating resistance in response to low frequency fluctuating infrared radiation impinging thereon, means for biasing said cells whereby a fluctuating signal is developed in response to said fluctuating radiation, means for amplifying said signal, fire alarm signalling means responsive to the presence and absence of the amplified signal, fire extinguishing means, and a time delay relay adapted to actuate said fire extinguishing means instantaneously upon the actuation of said time delay relay and deactuate said fire extinguishing means after a pre-set time delay beginning at the deactuation of said time delay relay, said time delay relay being actuated and deactuated by said fire alarm signalling means.

7. The apparatus of claim 6 including means for monitoring the operability of said amplifying means and the resistance of said cells, said monitoring means being adapted to lock-on said time delay relay in the event that a malfunction of said cells or amplifying means occurs after said time delay relay is actuated.

8. Fire detecting apparatus comprising, a photo-resistive cell adapted to provide a fluctuating resistance in response to low frequency fluctuating infrared radiation impinging thereon, a first supply of D.C. voltage, said first supply of voltage being adapted to bias said cell, a first amplifier stage coupled to said cell whereby a fluctuating signal is developed at the input of said first amplifier stage in response to said fluctuating radiation, a rectifying circuit adapted to convert a portion of said signal to D.C., a D.C. amplifier stage adapted to provide increased output current in response to an increased input bias, said D.C. amplifier stage being adapted to receive said D.C. signal, a second supply of D.C. voltage, said second supply of voltage being of opposite polarity than said signal and adapted to impress a selected bias on the input of said D.C. amplifier stage in opposition to said D.C. signal, a fire signal relay normally energized

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by the output of said D.C. amplifier stage acting in response to said bias on the input thereof whereby said fire signal relay is de-energized when said D.C. signal becomes great enough to decrease said bias on the input of said D.C. amplifier stage a predetermined amount, a trouble alarm circuit comprising signal generating means adapted to impress a monitor signal onto the cell bias of insufficient magnitude but within the correct frequency range to de-energize said fire signal relay, means responsive to the transmission of said monitor signal through said apparatus, said latter means being adapted to produce a signal in response to the interruption of monitor signal transmission or a predetermined decrease in the strength of the transmitted monitor signal and an electrical interlock between said fire signal relay and said monitor signal transmission responsive means, said interlock being operative to prevent said fire signal relay from producing a fire signal upon the de-energizing thereof in the event that the monitor signal transmission responsive means is actuated therewith in response to the interruption of or a predetermined decrease in the strength of the transmitted monitor signal.

9. Fire detecting apparatus comprising, a photo-resistive cell adapted to provide a fluctuating resistance in response to low frequency fluctuating infrared radiation impinging thereon, a first supply of D.C. voltage, said first supply of voltage being adapted to bias said cell, a first amplifier stage coupled to said cell whereby a fluctuating signal is developed at the input of said first amplifier stage in response to said fluctuating radiation, a rectifying circuit adapted to convert a portion of said signal to D.C., a D.C. amplifier stage adapted to provide increased output current in response to an increased input bias, said D.C. amplifier stage being adapted to receive said D.C. signal, a second supply of D.C. voltage, said second supply of voltage being of opposite polarity than said signal and adapted to impress a selected bias on the input of said D.C. amplifier stage in opposition to said D.C. signal, and a fire signal relay normally energized by the output of said D.C. amplifier stage acting in response to said bias on the input thereof whereby said fire signal relay is de-energized when said D.C. signal becomes great enough to decrease said bias on the input of said D.C. amplifier stage a predetermined amount, a trouble alarm circuit comprising, signal generating means adapted to impress a monitor signal onto the cell bias of insufficient magnitude but within the correct frequency range to de-energize said fire signal relay, means responsive to the transmission of said monitor signal through said apparatus, said latter means being adapted to produce a signal in response to the interruption of monitor signal transmission or a predetermined decrease in the strength of the transmitted monitor signal, said monitor signal being connected to ground through said cell whereby a decrease in resistance across said cell will attenuate said monitor signal, and a cell resistance monitoring circuit connected between the output of said cell and said A.C. amplifier stage, said resistance monitoring circuit being adapted to conduct current with a predetermined increase in resistance across said cell and bias the A.C. amplifier stage to saturation to destroy the gain thereof whereby the monitor signal is blocked or attenuated in response to a decrease or increase respectively in the resistance of said cell.

10. Fire detecting apparatus comprising, a plurality of spaced series interconnected photo-resistive cells adapted to provide a fluctuating resistance in response to low audio and sub-audio frequency fluctuating infrared radiation impinging thereon, a supply of positive relatively high voltage, said high voltage supply being adapted to bias said cells, a first compound connected transistor A.C. amplifier stage particularly sensitive to the low audio and sub-audio frequency range, said first A.C. amplifier stage being capacitively coupled to said cells whereby a fluctuating signal is developed at the input of said first

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A.C. amplifier stage in response to said fluctuating radiation, a second compound connected transistor A.C. amplifier stage, a filter network connected to the output of said first A.C. amplifier stage for attenuating noise in said signal, the output of said filter network being capacitively coupled to the input of said second A.C. amplifier stage, a rectifying circuit connected to the output of said second A.C. amplifier stage whereby a portion of the A.C. signal therefrom is converted to a D.C. signal of negative polarity, a compound connected transistor D.C. amplifier stage adapted to provide increased output current in response to an increased positive input bias, said D.C. amplifier stage being connected at the input thereof to said first rectifying circuit for receiving said D.C. negative signal, a supply of positive relatively low voltage, said low voltage supply being adapted to impress a selected positive bias on the input of said D.C. amplifier stage in opposition to said D.C. negative signal, and a fire signal relay normally energized by the output of said D.C. amplifier stage acting in response to said positive bias on the input thereof whereby said fire signal relay is de-energized when said D.C. negative signal becomes great enough to decrease the positive bias on the input of said D.C. amplifier stage a predetermined amount, a circuit monitoring network comprising, a neon bulb relaxation oscillator circuit adapted to impress a low frequency A.C. monitor signal onto said cell bias of insufficient magnitude but within the correct frequency range to de-energize said fire signal relay, said monitor signal being connected to ground through said cells whereby a decrease in resistance across said cell will cause an attenuation of said monitor signal, a neon bulb cell resistance monitoring circuit connected between the output of said cells and the emitter-base connection of said first A.C. amplifier stage and adapted to conduct current with a predetermined increase in resistance across said cells, the current conduction through said cell resistance monitoring circuit biasing said first A.C. amplifier stage into saturation whereby the monitor signal is blocked, a capacitance coupled connected to the output of said second A.C. amplifier stage for bypassing a portion of the A.C. output signal therefrom around said rectifying circuit to the input of said D.C. amplifier stage, a clamping circuit adapted to maintain a pre-selected positive bias voltage on said D.C. amplifier stage to retain the A.C. gain therethrough under conditions of large D.C. negative output from said rectifying circuit, the output of said D.C. amplifier stage being capacitively coupled to a third compound connected transistor A.C. amplifier stage for amplifying said A.C. monitor signal, a second rectifying circuit capacitively coupled to the output of said third A.C. amplifier stage for changing the amplified A.C. monitor signal to a D.C. positive monitor signal, a second compound connected transistor D.C. amplifier stage connected at the input thereof to said second rectifying circuit, and a trouble signal relay normally energized by the output of said second D.C. amplifier stage during biasing by said D.C. positive monitor signal, whereby the interruption or attenuation of the monitor signal in the fire detecting apparatus causes a de-energizing of said trouble relay.

11. Fire detecting apparatus comprising, a photo-resistive cell adapted to provide a fluctuating resistance in response to low frequency fluctuating infrared radiation impinging thereon, a first supply of D.C. voltage, said first supply of voltage being adapted to bias said cell, a first amplifier stage coupled to said cell whereby a fluctuating signal is developed at the input of said first amplifier stage in response to said fluctuating radiation, a rectifying circuit adapted to convert a portion of said signal to D.C., a D.C. amplifier stage adapted to provide increased output current in response to an increased input bias, said D.C. amplifier stage being adapted to receive said D.C. signal, a second supply of D.C. voltage, said second supply of voltage being of opposite polarity

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than said signal and adapted to impress a selected bias on the input of said D.C. amplifier stage in opposition to said D.C. signal, and a fire signal relay normally energized by the output of said D.C. amplifier stage acting in response to said bias on the input thereof whereby said fire signal relay is de-energized when said D.C. signal becomes great enough to decrease said bias on the input of said D.C. amplifier stage a predetermined amount, a first time delay relay, said first time delay relay being adapted to integrate multiple input signals impressed thereon, a normally open first set of contacts on said fire signal relay adapted to energize said first time delay relay upon the de-energizing of said fire signal relay, a second time delay relay adapted to close a normally open set of contacts upon the energizing thereof and open same after a pre-set time delay occurring after the de-energizing thereof a normally open set of contacts on said first time delay relay and adapted to close and thereby energize second time delay relay upon the completion of the first time delay relay cycle, and at least one fire extinguishing flow control adapted to permit fire extinguishing flow only when said set of second time delay relay contacts are closed whereby fire extinguishing commences

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upon the actuation of said second time delay relay and continues until the completion of a pre-set time delay beginning after the de-energizing of said second time delay relay.

12. The apparatus of claim 11 including means for monitoring the continuity of said first and second time delay relays and said fire extinguishing flow control.

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NEIL C. READ, *Primary Examiner.*