MINE SAFETY APPARATUS


19 Claims. (Cl. 317—9)

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The invention described herein may be manufactured and used by or for the Government of the United States for governmental purposes, without the payment to me of any royalty thereon.

The present invention relates to mine safety apparatus, and more particularly to mine safety apparatus that is used in conjunction with mining equipment that is electrically driven, the safety apparatus preventing the use of the electrically driven mining equipment in the presence of an explosive mixture of gas, particularly methane.

Summarily, in its broadest aspects, the present invention provides means to sense the presence of a gas mixture that is just enough, a heater for bimetallic strips being specifically utilized, and means operated in response to such presence to break the circuit of the engine of a mining machine including specifically a solenoid operated switch.

The mining industry, and particularly the coal mine industry, has had a history of disasters over the years. These disasters have been due to several diverse causes, and in more recent times considerable improvement has been made in the safety aspects of mining, along with improvements in mining methods and equipment. At the present time, many of the causes for mining disasters have become recognized and have been provided for; that is to say once these causes have become apparent, equipment, processes and safety steps have been taken or improved in order to combat the disaster potential in the mines.

As was alluded to above, mining methods and apparatus have been improved over a period of time, and of particular interest is the improvement in the actual cutting and removing of the mineral, particularly coal. For example, and a particular interest, is the fact that during the past approximately thirty years coal mining has changed from an almost manual method in which the coal was drilled, blasted and loaded, to a method involving the use of electrically driven machines that operate substantially continuously to cut the coal from the vein and continuously remove it. It may be briefly noted that this latter type of equipment falls into two categories: The ripper-type having a series of endless chains mounted on a cutting head and the boring-type, the latter being of more recent vintage and having the highest rate of production.

As is well known, there is always present in removing coal from the face of a cut a danger that an explosive gas will be liberated as the coal is separated from the face of the vein. In particular, this gas is frequently the greatly feared gas known as methane.

It is known that if the concentration of methane becomes high enough, the methane-air mixture is an explosive one and is liable to be ignited by a spark. It is also known that many of the things introduced into a mine can give off a spark and many steps have been taken to overcome the causing of a spark in a mine. Thus, all equipment introduced into the mines are subject to safety regulations which take into consideration the spark-producing ability of the equipment. This has included regulations governing the construction of electric motors that operate the above-mentioned continuous type mining apparatus, the intent being to prevent the arcing or sparking of the electric motor in the presence of the methane-air mixture.

Attempts have also been made to prevent the accumulation of methane in the mine, this being primarily by way of ventilation of the mine, and whereas ventilation has generally been successful in the "main" it has not been successful at the "face," that is at the place where the coal is being separated from the vein.

A further attempt at safety has been the provision of gas, particularly methane, detectors. Those typically in use include detectors that are provided for operation at periodic intervals by a miner specifically charged with that duty, so that periodic checks may be made to determine the presence of the explosive gas.

Despite all of the above enumerated attempts to avoid disasters in coal mining, it is regrettable to say that disasters are still occurring; in the year 1957 there occurred at least twenty-two "ignitions" or explosions at mine working faces in the United States, and there were killed in these explosions fifty-five men. In all cases, it was the conclusion of those best qualified to judge that the source of the ignition was in mechanized, electrically operated mining equipment.

An object of the present invention is to provide mine safety apparatus for preventing the operation of mining equipment in the presence of a build-up of explosive gas, particularly methane.

Another object of the present invention is the provision of mine safety apparatus that will detect the presence of explosive gas, particularly methane, and will give a warning thereof; upon continued build-up of the methane to stop the mining equipment.

A further object of the present invention is to provide mine safety apparatus that is of rugged construction, that will function properly even after long periods of use under the adverse conditions that are extant in mines.

Yet another object of the present invention is the provision of mine safety apparatus that is fail-safe.

A still further object of the present invention is to provide mine safety apparatus for mining equipment that cannot be circumvented or intentionally caused to function in the presence of a pro-explosive concentration of gases, such as methane.

A further object of the present invention is the provision of mine safety apparatus that will prevent the operation of mining equipment if the safety apparatus itself is not in proper working order.

Other objects and the nature and advantages of the instant invention will be apparent from the following description taken in conjunction with the accompanying drawings, wherein:

FIG. 1 shows an illustrative embodiment of the invention.

FIG. 2 is a plan view of a methane detector apparatus in accordance with the present invention.

FIG. 3 is a cross-section taken on the line 3—3 of FIG. 2.

FIG. 4 is an exploded view of an intake hose forming a part of the methane detector.

Referring now to the drawings, wherein like reference numerals are used to designate like or corresponding parts throughout the several views, there is shown in FIG. 1 a pair of power supply lines L1 and L2, and it will be understood that the lines L1 and L2 correspond to the power cables in a mine, and these lines supply electric current to the motor 10 of a piece of mining equipment, such as for example, a ripper-type continuous miner or a boring-type continuous miner. The lines L1 and L2 supply, in a typical installation, 275 volt direct current, and in order to reduce this voltage, a motor generator set 11 is connected to the lines L1 and L2 and from the generator of the set 11 there extend first and second conductors 12 and 13, respectively. If desired, a rheostat 14 may be connected in the conductor 12, and in a typical installation will serve to reduce the output voltage of the
motor generator set 11 from 24 volts direct current to 12 volts direct current.

A housing 16, 22 and described in greater detail hereinafter, has a first bimetallic element 17 and a second bimetallic element 18 therein, these elements 17 and 18 being connected to the conductor 12 in parallel. Bimetallic element 17 and bimetallic element 18 are both movable, towards the right as shown in FIG. 1, upon an increase in ambient temperature thereof, but the bimetallic element 17 is movable in response to a lower temperature than the bimetallic element 18. A heater unit generally designated 19 is also seen in the housing 16, and as will be explained later is in juxtaposition with the bimetallic elements 17 and 18.

A contact 21 is positioned in the housing 16 and is adapted to be engaged by the bimetallic element 17 upon heating thereof. A second contact 22 is positioned to be engaged by bimetallic element 18 in the cold or unheated position thereof and a third contact 23 is positioned to be engaged by the bimetallic element 18 in the heated position thereof.

Connected to the first contact 21 is an alarm circuit 25 that is also connected to the second conductor 13 and includes an alarm bell 26.

A cut-off relay circuit 27 is connected between the second contact 22 and the second conductor 13, and includes conductors 28, 29, 30 and the coil 32 of a cut-off relay. The cut-off relay has contacts 33 that are normally open and form part of a control circuit 36 having conductors 37 and 38 that are connected to the power supply lines L1 and L2, the conductor 38 having therein the solenoid winding 39 of a solenoid operated switch 41. The switch 41 is in the power supply line L1, and may thus be seen to be a control switch for the mining machine motor 10.

A fail-safe relay circuit 44-46 is connected in parallel with the first and second conductors 12 and 13, and includes a conductor 44 connected to conductor 12 and to the coil 45 of a fail-safe relay, the other side of coil 45 being connected by conductor 46 to the conductor 30. A fail-safe contact circuit 47 comprises conductors 48 and 49 that are connected in parallel with the conductors 37 and 38 of a control circuit 36, and includes the normally open contacts 51 that are opened upon energization by the coil 45 of the fail-safe relay.

To provide a warning of methane gas build-up, a danger warning circuit 53 is connected between the second contact 22 and the second conductor 13, the danger warning circuit 53 comprising a conductor 54 that is connected with the conductor 26, a flasher 55, a conductor 56, a red light 57, and a conductor 58 that is connected to conductor 13.

Connected to the third contact 23 and to the conductor 13 is an auxiliary relay circuit 60 comprising a conductor 61 connected to the contact 23 and to one side of a coil 62 of an auxiliary relay. The other side of the coil 62 is connected by a conductor 63 to the conductor 13. A first pair of normally open contacts 64 that are controlled by the coil 62 are connected by a conductor 66 to the conductor 61 on the one hand and by a conductor 67 to the conductor 26 on the other hand.

A heater circuit 68 is connected between the conductors 12 and 13 and includes the heater unit 19, a voltage maintaining device 69 of known construction, a conductor 70 between said voltage maintaining device 69 and the heater 71, a conductor 72 between the device 69 and the conductor 13, a conductor 73 between the heater 19 and a fixed contact 74. A movable contact 73, under the control of coil 62, is normally urged against the contact 73, and is connected by a conductor 75 with the conductor 12.

A holding relay circuit 80 extends from the fixed contact 81 to the conductor 13, and includes the conductor 82 that extends from the contact 81 (engageable by the movable contact 74) to one side of the coil 83 of a holding relay, the other side of which is connected by a conductor 84 to the conductor 13. As will be apparent, a circuit will be completed through the elements just enumerated, plus the movable contact 74 and the conductor 75 to the conductor 12. A pair of normally open contacts 85 is closed upon energization of the coil 83, and the contacts 85 are connected by a conductor 86 to the conductors 28 and 29, and by a conductor 87 to the conductor 12.

In order to indicate that the apparatus is "on," an "on" indicating circuit 88 is connected between the conductors 12 and 13, and includes a green indicating light 89.

Also connected in parallel with the conductors 12 and 13 is the motor of a motor operated fan 90.

Referring now to FIG. 2, there may be seen therein a plan view of the detector for methane, the detector comprising the aforementioned housing 16, which is of the permissible type and is equipped with flashlight arresters. Housing 16 has therein the bimetallic elements 17 and 18 and the heater unit 19. The bimetallic elements 17 and 18 are mounted in a combustion chamber 100 that is defined by the front wall 101 of the housing 16, a partition wall 102 at right angles to the front wall 101 and a rear partition wall 103 parallel to the front wall 101. The bimetallic elements 17 and 18 are mounted on a base 104 that is secured to the front wall 101. A support 106 extends from the base 104 and an adjusting screw 107 is threaded engaged therein and has one end thereof in engagement with the bimetallic element 18. The screw 107 may conveniently have a pointer element 108 attached to it to indicate the degree of turning of it. A similar support 109, screw 107 and indicator 108 are provided for the bimetallic element 17.

The heater unit 19 is positioned beneath the bimetallic elements 17 and 18, as may be seen from FIG. 3, and is of extremely sturdy construction so as to be enabled to function despite the almost continuous bumps, jolts and rough usage to which it is subjected. The heater unit 19 comprises a flameproof socket 110 that is secured to the side wall of the housing 16 and receives the screw threaded end of a ceramic rod 111. A cross rod 112 is attached at its midpoint to the opposite end of the rod 111, so as to form a T-shaped support, the rod 112 having grooves therein in which are positioned a heater wire 113, the ends of which extend into the socket 110.

An outlet 115 is provided from the combustion chamber 100, and an inlet duct 116 extends along the bottom of combustion chamber 100 through the dividing wall 102 and has an upstanding vent 117 beneath the cross rod 112, as may be seen in FIG. 3.

A temperature indicator 118 is shown in FIG. 3 mounted in the front wall 101 of the housing 16, the temperature indicator 118 not being shown in FIG. 2 for purposes of clarity. The temperature sensitive element 119 of the indicator 118 extends above the rod 112 and has a dial 120 that is calibrated in methane concentration percentage. The dial 120 is protected in known manner by a shatterproof glass and a guard surrounding it.

A motor chamber 122 and a fan chamber 123 may be seen in the housing 16 in FIG. 2. An inlet 124 is provided into the motor chamber 122 and a motor 126 is positioned in the motor chamber 122. This motor 126 is the motor of the motor-driven fan 90, the fan having been shown in the fan chamber 123 and supported on a shaft 127 of the motor 126, the shaft 127 extending through an aperture 128 in the dividing wall 129. As will be readily understood, upon energization of the motor 126 the fan 90 will cause air to flow through the inlet 124, the aperture 128 and thence into 115 through the duct 116.

A top, not shown, is provided for the housing 16 and is readily removable to permit access to the chambers 109, 122 and 123; if desired, a lock may be placed on the top so that unauthorized entry into the housing 16 may be prevented, thus to prevent unauthorized persons from making any changes or adjustments to the various parts within housing 16, and in particular to the two ad-
justing screws 107. Also, if desired, the top for the housing 16 may be divided into two parts, one for the combustion chamber 100 and the other for the chambers 122 and 123.

The inlet 124 has connected therewith a fitting 130 that is secured to the wall of the housing 16, this fitting 130 comprising an annular conduit 131 that receives on the end thereof a filter 132, the filter having oppositely extending flanges 133 and 134 to engage the conduit 131 and a rubber hose 135, respectively. Adequate securing means, not shown, are provided to retain the conduit 131, the filter 132, and the hose 135 in assembled relationship. The opposite end of hose 135 is closed, as at 136 and has a plurality of openings 137 spaced slightly from the end thereof for the purposes of admitting gas or air, or a mixture of the two. A screen 138 is preferably placed closely inside of the hoses 137.

In operation, the housing 116 is mounted upon a mining machine, preferably one of the types above mentioned, the mining machine being driven by the motor 10. As soon as current is drawn through the power supply lines L1 and L2 to drive the motor 10, the motor generator set 11 will become operative to drive the motor 126 and the fan 109 that is connected to it. The "on" indicating circuit 88 will be energized and the green light 89 will therefore indicate that the equipment is on. If the motor generator set 11 is operating properly so as to cause a circuit through the conductors 12 and 13, the safe-fail relay circuit 43 will be energized to thereby open the contacts 51 and thus prevent a circuit through the control circuit 36 and the solenoid 39 thereof. In consequence, the solenoid operated switch 41 will remain closed. Alternatively, should there be a malfunctioning so as to prevent the completion of a current through conductors 12 and 13, the coil 45 will not be energized, the contacts 51 will remain closed and the solenoid 39 will accordingly be energized to open the switch 41 and prevent the operation of the mining machine motor 10.

Assuming the proper operation and the completion of a circuit through conductors 12 and 13, it will be understood that the heater unit 19 does not immediately become heated, and so accordingly the bimetallic element 18 will be in engagement with the second contact 22 and thus the danger warning circuit 53 will be energized, causing the red light 57 to flash, the circuit being completed from conductor 12 through the bimetallic element 18, the contact 22, the conductors 28 and 54, the flasher 55, the red light 57 and the conductor 58 to the conductor 13. Also, the cut-off relay circuit 27 will be completed through conductor 28, conductor 29, coil 32 and conductor 30 to the conductor 13. This will cause the contacts 33 to be closed to thus complete the control circuit 36 and open the solenoid operated switch 41 to prevent operation of the motor 10 of the mining machine. The purpose of the circuitry described immediately above is to prevent the mining machine from being operated until the heater unit 19 has reached its proper operating temperature.

It will be understood that after a period of time the heater unit 19 will reach its operating temperature since the heater circuit 68 is completed from conductor 12 through conductor 75, movable contact 74, fixed contacts 73, conductor 72, the heater unit 19, conductor 70, voltage maintaining device 69 and conductor 71 to conductor 13. As the wire 113 of the heater unit 19 reaches its operating temperature, the surrounding wire 113 will become heated and this heat will be transferred to the bimetallic element 18 so as to cause it to assume a neutral position between the second contact 22 and the third contact 23; it will be understood that the neutral position is maintained so long as there is no methane present in the air in the combustion chamber 130, as the concentration is below a predetermined minimum.

Once the bimetallic element 18 is out of engagement with the second contact 22, the danger warning circuit 53 and the cut-off relay circuit 27 will be opened, thus permitting the closing of the solenoid operated switch 41 and the completion of a circuit to and through the motor 10.

In the event that methane gas begins to accumulate at the working space, it will be drawn in through the holes 137 in the tube 135, and will pass through the tube 135, the fitting 130, inlet 134, chamber 132, duct 116 and will be discharged onto the wire 113 of the heater unit 19. The methane-air mixture will be burned, and thus the temperature in the combustion chamber 100 will be raised. An indication of the percentage concentration will be given by the temperature indicator 118; should the methane concentration percentage approach, for example, 1.25%, the bimetallic element 17 will move into engagement with the first contact 21 and will thus complete the alarm circuit 25 so as to cause the bell 26 to sound.

At a concentration of 1.25%, the methane is not generally considered to be dangerous or explosive. However, the sounding of the alarm bell 25 will indicate the presence of methane at the face and corrective measures can then be taken without a costly and uneconomical shut down of the mining equipment. Thus, the miners may quickly institute a program of methane gas surveillance as well as undertake corrective measures such as the checking of the mine ventilation and/or the institution of emergency ventilation procedures.

If, despite the above mentioned efforts, the methane gas concentration continues to build up, and the percentage of concentration approaches even closer to the danger point, such as for example 2.5%, the bimetallic element 18 will be moved from its neutral position into engagement with the third contact 23. This will complete the auxiliary relay circuit 60 from conductor 12 through the bimetallic element 18, contact 23, conductor 61, coil 62 of the auxiliary relay, and conductor 63 to conductor 13. Energization of coil 62 will close the contacts 64 so that a circuit will be completed from the conductor 61 through conductor 66, the contacts 64, conductor 67, and the danger warning circuit 53 to cause the red light 57 to flash. Also, the cut-off relay circuit 27 will be completed, from the conductor 67 through the conductor 28, the conductor 29, coil 32 of the cut-off relay and conductor 30 to the conductor 13. Energization of coil 32 will cause the contacts 33 to close, as above described, to energize the solenoid operated switch 41 and to thereby break the circuit to the mining machine motor 10. Thus, it will be seen that upon the methane concentration reaching a predetermined amount the mining machine motor will be instantly de-energized by breaking of the power supply to it.

As a further consequence of the energization of coil 62 of the auxiliary relay upon engagement of bimetallic element 18 with the third contact 23, the movable contact 74 will be shifted to the left so as to break or open the heater circuit 68 by breaking the engagement of movable contact 74 and fixed contact 73. Movable contact 74 will engage the fixed contact 81, thus to complete a circuit from conductor 12 through conductor 75, contacts 74 and 81, conductor 82, coil 83, and conductor 84 to conductor 13, this being above referred to as the holding relay circuit 80.

Energization of the coil 83 will cause the contacts 85 to close, and thus a circuit will be completed from conductor 12 through conductor 87, contacts 85, conductor 86, conductor 29, coil 32 and conductor 30 to conductor 13 and consequently the solenoid switch 41 will be opened in the manner above described. In addition, a circuit will be completed from conductor 12 through conductor 87, contacts 85, conductors 86, conductor 28, conductor 67, contacts 64, conductor 66, conductor 61, coil 62, and conductor 62 to conductor 13; as will be understood, this is a holding circuit that will cause the coil 62 to be
energized so as to engage the contacts 64 and also the contacts 74 and 81. It will be understood, therefore, that with the above circuitry, so long as power is supplied to the conductors 12 and 13 to complete a circuit therethrough, once the bimetallic element 18 has engaged the third contact 23, the only way to restore power to the motor 10 is to disconnect the power supply lines L1 and L2. Hence, to restore power to the motor 10, it is necessary to disconnect the power supply lines L1 and L2, and it will be understood that these are usually incorporated in a trailing cable leading from the mining machine back to a source of power supply, such as a connection box located in the mine. Thus, it will be necessary for one of the miners to go back to the end of the trailing cable, to disconnect it from the power supply and to then reconnect it. During this time the heater unit 19 will have cooled and so the bimetallic element 18 will have returned to engagement with the second contact 22. It will be understood, of course, that the holding circuits above described will cause the solenoid operated switch 41 to remain open once the bimetallic element 18 has engaged contact 23, so that on disengagement of the contact 23 the solenoid operated switch 41 will still remain open.

Upon reconnection of the power supply lines L1 and L2, both in the same condition that it was at the beginning. With bimetallic element 18 in engagement with the second contact 22, and thus the motor 10 will not be energized until after the heater unit 19 has reached its operating temperature, and only if the methane concentration is below the predetermined amount, in instance 2.5%, in which case bimetallic element 18 will move to its aforementioned neutral position.

There has been provided mine safety apparatus that is ruggedly constructed so that it may be mounted upon mining equipment and withstand the hard usage inherent in mining operations. The equipment is fail-safe, and prevents energization of the mining machine motor until the detector thereof is in operating condition, as regards the heater unit 19, and is otherwise in proper condition. There is a visual indication provided of the methane concentration, and an alarm signal given at a relatively low methane concentration. Upon the attainment of a higher, pre-explosive methane concentration, the power to the mining machine motor is cut off, and remains cut off until the trailing cable is disconnected and reconnected at the source of power supply. This latter is accomplished by holding circuitry that causes the power supply to the mining machine to be cut off even if the methane concentration becomes lower, until the noted disconnection and reconnection of the trailing cable.

It will be obvious to those skilled in the art that various changes may be made without departing from the spirit of the invention and therefore the invention is not limited to what is shown in the drawings and described in the specification, but only as indicated in the appended claims.

What is claimed is:

1. In mine safety apparatus, an electric motor for operating a mining machine, power supply lines connected to said motor, a first conductor connected to one of said power supply lines and having a pair of bimetallic elements connected therewith in parallel, a first of said bimetallic elements being movable in response to a lower temperature and a second bimetallic element being responsive to a higher temperature, a heater unit in juxtaposition with said bimetallic elements, a contact positioned to be engaged by said bimetallic element upon heating thereof, a second conductor connected to another of said power supply lines, an alarm circuit between the contact of said first bimetallic element and said second conductor including an alarm bell, second and third contacts positioned to be engaged by said second bimetallic element in the unheated and heated positions thereof, respectively, a cut-off relay circuit between said second contact and said second conductor and including a cut-off relay coil, a control circuit connected in parallel with said power supply lines and including normally open contacts closed by said cut-off relay coil and the solenoid of a solenoid operated mining machine motor control switch, said switch being in one of said power supply lines, a fail-safe relay circuit between said second conductor and including a fail-safe relay coil, a fail-safe contact circuit connected to and in parallel with said control circuit and including normally open contacts closed by the fail-safe relay coil, a danger warning circuit between said second contact and said second conductor and including a flasher and a warning light, an auxiliary relay circuit between said third contact and said second conductor and including an auxiliary relay coil, a first pair of normally closed contacts closed by said auxiliary relay coil and connected to said auxiliary relay circuit and said cut-off relay circuit, a heater circuit between said first and second conductors and including said heater unit, a voltage maintaining device and a second pair of normally closed contacts operable by said auxiliary relay coil, a holding relay circuit between a fifth contact of said auxiliary relay and said second conductor and including a holding relay coil, said fifth contact being connected to said first conductor when said auxiliary relay circuit is closed, a pair of normally closed contacts closed by said holding relay coil and connected to said first conductor and said cut-off relay circuit, an "on" indicating circuit between said first and second conductors including an indicating light, a motor-operated fan having the motor thereof connected to said first and second conductors, a housing containing said fan, said bimetallic elements and said heater unit, and means to conduct gas to said housing and to permit gas to leave said housing.

2. The apparatus of claim 1, said heater unit comprising a ceramic rod having one end thereof screw-threaded, an integral ceramic cross rod at the other end of said first mentioned rod, grooves in said cross rod, and a heater wire in said grooves.

3. The apparatus of claim 1, said housing having a combustion chamber therein, said heater unit being in said combustion chamber, said pair of bimetallic elements being in said combustion chamber above said heater unit, a pair of supports extending generally parallel to said elements and each having an adjusting screw threaded therein and engageable with each of said elements to adjust the same, a pointer attached to each of said screws, an outlet from said combustion chamber, a temperature indicator mounted on the front wall of said combustion chamber and having a temperature sensitive element in said combustion chamber, a motor chamber and a fan chamber in said housing, an inlet into said motor chamber, the motor of said motor-operated fan in said motor chamber, a dividing wall between said two last mentioned chambers having an opening therein, a shaft extending from said motor, through said opening and supporting said fan thereon in said fan chamber, a duct in said housing leading from said fan chamber and discharging beneath said heater unit in said combustion chamber, and an intake hose having one end free and the other end connected to said inlet.

4. In mine safety apparatus, an electric motor for operating a mining machine, power supply lines connected to said motor, a first conductor connected to one of said power supply lines and having a pair of bimetallic elements connected therewith in parallel, a first of said bimetallic elements being movable in response to a lower temperature and a second bimetallic element being responsive to a higher temperature, a heater unit in juxtaposition with said bimetallic elements, a contact positioned to be engaged by said bimetallic element upon heating thereof, a second conductor connected to another of said power supply lines, an alarm circuit between the contact of said first bimetallic element and said second conductor including an alarm bell, second and third contacts positioned to be engaged by said second bimetallic element in the unheated and heated positions thereof, respectively, a cut-off relay circuit between said second contact and said second conductor and including a cut-off relay coil, a control circuit connected in parallel with said power supply lines and including normally open contacts closed by said cut-off relay coil and the solenoid of a solenoid operated mining machine motor control switch, said switch being in one of said power supply lines, a fail-safe relay circuit between said second conductor and including a fail-safe relay coil, a fail-safe contact circuit connected to and in parallel with said control circuit and including normally open contacts closed by the fail-safe relay coil, a danger warning circuit between said second contact and said second conductor and including a flasher and a warning light, an auxiliary relay circuit between said third contact and said second conductor and including an auxiliary relay coil, a first pair of normally closed contacts closed by said auxiliary relay coil and connected to said auxiliary relay circuit and said cut-off relay circuit, a heater circuit between said first and second conductors and including said heater unit, a voltage maintaining device and a second pair of normally closed contacts operable by said auxiliary relay coil, a holding relay circuit between a fifth contact of said auxiliary relay and said second conductor and including a holding relay coil, said fifth contact being connected to said first conductor when said auxiliary relay circuit is closed, a pair of normally closed contacts closed by said holding relay coil and connected to said first conductor and said cut-off relay circuit, an "on" indicating circuit between said first and second conductors including an indicating light, a motor-operated fan having the motor thereof connected to said first and second conductors, a housing containing said fan, said bimetallic elements and said heater unit, and means to conduct gas to said housing and to permit gas to leave said housing.
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9. tacts positioned to be engaged by said second bimetallic element in the unheated and heated positions thereof, respectively, a cut-off relay circuit between said second contact and said second conductor and including a cut-off relay coil, a control circuit connected in parallel with said power supply lines and including normally open contacts closed by said second conductor and including a switch of a solenoid operated mining machine motor control switch, said switch being in one of said power supply lines, a fail-safe relay circuit between said first and second conductors and including a fail-safe relay coil, a fail-safe contact circuit connected to and in parallel with said control circuit and including normally open contacts closed by the fail-safe relay coil, a danger warning circuit connected between said second contact and said second conductor and including a flasher and a warning light, an auxiliary relay circuit between said third contact and said auxiliary relay coil, a first pair of normally open contacts closed by said auxiliary relay coil and connected to said auxiliary relay circuit and said cut-off relay circuit, a heater circuit between said first and second conductors and including said heater unit, a voltage maintaining device and a second pair of normally open contacts connected to said auxiliary relay coil, a holding relay circuit between a fifth contact of said auxiliary relay and said second conductor and including a holding relay coil, said fifth contact being connected to said first conductor when said auxiliary relay circuit is closed, a pair of normally open contacts closed by said holding relay coil and connected to said second conductor and including said cut-off relay circuit, a motor-operated fan having the motor thereof connected to said first and second conductors, a housing containing said fan, said bimetallic elements and said heater unit, and means to conduct gas to said housing and to permit gas to leave said housing.

5. In mine safety apparatus, an electric motor for operating a mining machine, power supply lines connected to said motor, a first conductor connected to one of said power supply lines and having a pair of bimetallic elements connected therewith in parallel, a first of said bimetallic elements being movable in response to a lower temperature and a second bimetallic element being responsive to a higher temperature, a heater unit in juxtaposition with said bimetallic elements, a contact positioned to be engaged by said first bimetallic element upon heating thereof, said second conductor connected to another of said power supply lines, an alarm circuit between the contact of said first bimetallic element and said second conductor including an alarm bell, second and third contacts positioned to be engaged by said second bimetallic element in the unheated and heated positions thereof, respectively, a cut-off relay circuit between said second contact and said second conductor and including a cut-off relay coil, a control circuit connected in parallel with said power supply lines and including normally open contacts closed by said cut-off relay coil and the solenoid of a solenoid operated mining machine motor control switch, said switch being in one of said power supply lines, a fail-safe relay circuit between said first and second conductors and including a fail-safe relay coil, a fail-safe contact circuit connected to and in parallel with said control circuit and including normally open contacts closed by said fail-safe relay coil, a danger warning circuit between said second contact and said second conductor and including an auxiliary relay coil, a holding relay circuit between a fifth contact of said auxiliary relay and said second conductor and including a holding relay coil, said fifth contact being connected to said first conductor when said auxiliary relay circuit is closed, a pair of normally open contacts closed by said holding relay coil and the solenoid of a solenoid operated mining machine motor control switch, said switch being in one of said power supply lines, a fail-safe relay circuit between said first and second conductor and including a fail-safe relay coil, a fail-safe contact circuit connected in parallel with said control circuit and including normally open contacts closed by said fail-safe relay coil, a danger warning circuit between said first contact and said second conductor and including a cut-off relay coil, a control circuit connected in parallel with said power supply lines and including normally open contacts closed by said cut-off relay coil and the solenoid of a solenoid operated mining machine motor control switch, said switch being in one of said power supply lines, a fail-safe relay circuit connected to and in parallel with said control circuit and including normally open contacts closed by said fail-safe relay coil, a danger warning circuit between said first and second conductors and including an auxiliary relay coil, a first pair of normally open contacts closed by said auxiliary relay coil and connected to said auxiliary relay circuit and said cut-off relay circuit, a heater circuit between said first and second conductors and including said heater unit, a voltage maintaining device and a second pair of normally open contacts connected to said auxiliary relay coil, a holding relay circuit between a fifth contact of said auxiliary relay and said second conductor and including a holding relay coil, said fifth contact being connected to said first conductor when said auxiliary relay circuit is closed, a pair of normally open contacts closed by said holding relay coil and said auxiliary relay coil and connected to said auxiliary relay circuit and said cut-off relay circuit, a heater circuit between said first and second conductors and including said heater unit, a voltage maintaining device and a second pair of normally open contacts closed by said holding relay coil and said auxiliary relay coil and connected to said auxiliary relay circuit and said cut-off relay circuit, a “on” indicating circuit between said first and second conductors including an indicating light, a motor operated fan having the motor thereof connected to said control circuit and said second conductor, a housing containing said fan, said bimetallic element and said heater unit, and means to conduct gas to said housing and to permit gas to leave said housing.

6. In mine safety apparatus, an electric motor for operating a mining machine, power supply lines connected to said motor, a first conductor connected to one of said power supply lines and connected with a bimetallic element, a heater unit in juxtaposition with said bimetallic element, a second conductor connected to another of said power supply lines, a pair of contacts positioned to be engaged by said bimetallic element in the unheated and heated positions thereof, respectively, a cut-off relay circuit between a first contact and said second conductor and including a cut-off relay coil, a control circuit connected in parallel with said power supply lines and including normally open contacts closed by said cut-off relay coil and the solenoid of a solenoid operated mining machine motor control switch, said switch being in one of said power supply lines, a fail-safe relay circuit between said first and second conductor and including a fail-safe relay coil, a fail-safe contact circuit connected in parallel with said control circuit and including normally open contacts closed by the fail-safe relay coil, a danger warning circuit between said first contact and said second conductor and including an auxiliary relay coil, a first pair of normally open contacts closed by said auxiliary relay coil and connected to said auxiliary relay circuit and said cut-off relay circuit, a heater circuit between said first and second conductors and including said heater unit, a voltage maintaining device and a second pair of normally open contacts closed by said auxiliary relay coil and connected to said auxiliary relay circuit and said cut-off relay circuit, a “on” indicating circuit between said first and second conductors including an indicating light, a motor operated fan having the motor thereof connected to said control circuit and said second conductor, a housing containing said fan, said bimetallic element and said heater unit, and means to conduct gas to said housing and to permit gas to leave said housing.

7. In mine safety apparatus an electric motor for operating a mining machine, power supply lines connected to said motor, a first conductor connected to one of said power supply lines and connected with a bimetallic element, a heater unit in juxtaposition with said bimetallic element, a second conductor connected to another of said power supply lines, a pair of contacts positioned to be engaged by said bimetallic element in the unheated and heated positions thereof, respectively, a cut-off relay circuit between a first contact and said second conductor and including a cut-off relay coil, a control circuit connected in parallel with said power supply lines and including normally open contacts closed by said cut-off relay coil and the solenoid of a solenoid operated mining machine motor control switch, said switch being in one of said power supply lines, a fail-safe relay circuit connected to and in parallel with said control circuit and including normally open contacts closed by said fail-safe relay coil, a danger warning circuit between said second contact and said second conductor and including a flasher and a warning light, an auxiliary relay circuit between said third contact and said auxiliary relay coil, a first pair of normally open contacts connected to said auxiliary relay coil, a second pair of normally open contacts closed by said auxiliary relay coil, a holding relay circuit between a fifth contact of said auxiliary relay and said second conductor and including a holding relay coil, said fifth contact being connected to said first conductor when said auxiliary relay circuit is closed, a pair of normally open contacts closed by said holding relay coil and connected to said auxiliary relay circuit and said cut-off relay circuit, a danger warning circuit between said first contact and said second conductor and including a cut-off relay coil, a control circuit connected in parallel with said power supply lines and including normally open contacts closed by said cut-off relay coil and the solenoid of a solenoid operated mining machine motor control switch, said switch being in one of said power supply lines, a fail-safe relay circuit between said first and second conductor and including a fail-safe relay coil, a fail-safe contact circuit connected in parallel with said control circuit and including normally open contacts closed by the fail-safe relay coil, a danger warning circuit between said first contact and said second conductor and including an auxiliary relay coil, a first pair of normally open contacts closed by said auxiliary relay coil and connected to said auxiliary relay circuit and said cut-off relay circuit, a heater circuit between said first and second conductors and including said heater unit, a voltage maintaining device and a second pair of normally open contacts closed by said auxiliary relay coil and connected to said auxiliary relay circuit and said cut-off relay circuit, a “on” indicating circuit between said first and second conductors including an indicating light, a motor operated fan having the motor thereof connected to said control circuit and said second conductor, a housing containing said fan, said bimetallic element and said heater unit, and means to conduct gas to said housing and to permit gas to leave said housing.
of normally open contacts closed by said auxiliary relay coil and connected to said auxiliary relay circuit and said cut-off relay circuit, a heater circuit between said first and second conductors and including said heater unit and a second pair of normally closed contacts openable by said auxiliary relay coil, a holding relay circuit between a fifth contact of said auxiliary relay and said second conductor and including a holding relay coil, said fifth contact being connected to said first conductor when said auxiliary relay circuit is closed, a pair of normally open contacts closed by said holding relay coil and connected to said first conductor and said cut-off relay circuit, and means to cause sample gas to flow across said heater and said bimetallic element.

9. In mine safety apparatus, an electric motor for operating a mining machine, power supply lines connected to said motor, a first conductor connected to one of said power supply lines and connected with a bimetallic element, a heater unit in juxtaposition with said bimetallic element, a second conductor connected to another of said power supply lines, a pair of contacts positioned to be engaged by said bimetallic element in the unheated and heated positions thereof, respectively, a cut-off relay circuit between a first contact and said second conductor and including a cut-off relay coil, a control circuit connected in parallel with said power supply lines and including normally open contacts closed by said cut-off relay coil and the solenoid of a solenoid operated mining machine motor control switch, said switch being in one of said power supply lines, a danger warning circuit connected between said first contact and said second conductor and including a flasher and a warning light, an auxiliary relay circuit between the second contact and said second conductor and including an auxiliary relay coil, a pair of normally open contacts closed by said auxiliary relay coil and connected to said auxiliary relay circuit and said cut-off relay circuit, a heater circuit between said first and second conductors and including said heater unit and a second pair of normally closed contacts openable by said auxiliary relay coil, a holding relay circuit between a fifth contact of said auxiliary relay and said second conductor and including a holding relay coil, said fifth contact being connected to said first conductor when said auxiliary relay circuit is closed, a pair of normally open contacts closed by said holding relay coil and connected to said first conductor and said cut-off relay circuit, and means to cause sample gas to flow across said heater and said bimetallic element.

10. In mine safety apparatus, an electric motor for operating a mining machine, power supply lines connected to said motor, a first conductor connected to one of said power supply lines and connected with a bimetallic element, a second conductor connected to another of said power supply lines, a pair of contacts positioned to be engaged by said bimetallic element in the unheated and heated positions thereof, respectively, a cut-off relay circuit between a first contact and said second conductor and including a cut-off relay coil, a control circuit connected in parallel with said power supply lines and including normally open contacts closed by said cut-off relay coil and the solenoid of a solenoid operated mining machine motor control switch, said switch being in one of said power supply lines, an auxiliary relay circuit between the second contact and said second conductor and including an auxiliary relay coil, a pair of normally open contacts closed by said auxiliary relay coil and connected to said auxiliary relay circuit and said cut-off relay circuit, a heater circuit between said first and second conductors and including said heater unit, a holding relay circuit between another contact of said auxiliary relay and said second conductor and including a holding relay coil, said fifth contact being connected to said first conductor when said auxiliary relay circuit is closed, a pair of normally open contacts closed by said holding relay coil and connected to said first conductor and said cut-off relay circuit, and means to cause sample gas to flow across said heater and said bimetallic element.

11. In a detector, a housing having a combustion chamber therein, a heater unit in said combustion chamber, a pair of bimetallic elements in said combustion chamber above said heater unit, a first contact positioned to be engaged by one of said elements when heated, said one element being responsive to a relatively low temperature, the second element being responsive to a relatively higher temperature, a second contact positioned to be engaged by said second element when unheated, a third contact positioned to be engaged by said second element when heated, a pair of supports extending generally parallel to said elements and each having an adjusting screw threaded therein and engageable with each of said elements, a mechanism means to adjust the same, a pair of said screws, an outlet from said combustion chamber, a temperature indicator mounted on the front wall of said combustion chamber and having a temperature sensitive element in said combustion chamber, a motor chamber and a fan chamber in said housing, an inlet into said motor chamber, a motor therein, a dividing wall between said two last mentioned chambers having an opening therein, a shaft extending from said motor, through said opening and supporting a fan thereon in said fan chamber, a duct in said housing leading from said fan chamber and discharging beneath said heater unit in said combustion chamber, and an intake hose having one end free and the other end connected to said inlet.

12. In a detector, a housing having a combustion chamber therein, a heater unit in said combustion chamber, a pair of bimetallic elements in said combustion chamber above said heater unit, said elements being of different sensitivities, closed by said auxiliary relay coil and connected with a cut-off relay circuit and said cut-off relay coil and connected to said auxiliary relay circuit and said cut-off relay circuit, a heater circuit between said first and second conductors and including said heater unit and a second pair of normally closed contacts openable by said auxiliary relay coil, a holding relay circuit between a fifth contact of said auxiliary relay and said second conductor and including a holding relay coil, said fifth contact being connected to said first conductor when said auxiliary relay circuit is closed, a pair of normally open contacts closed by said holding relay coil and connected to said first conductor and said cut-off relay circuit, and means to cause sample gas to flow across said heater and said bimetallic element.
13. In a detector, a housing having a combustion chamber therein, a heater unit in said combustion chamber, a pair of bimetallic elements in said combustion chamber above said heater unit, a first contact positioned to be engaged by one of said elements when heated, said one element being responsive to a relatively low temperature, the second element being responsive to a relatively higher temperature, a second contact positioned to be engaged by said second element when unheated, a third contact positioned to be engaged by said second element when heated, a pair of supports extending generally parallel to said elements and each having an adjusting screw threaded therein and engageable with each of said elements to adjust the same, a pointer attached to each of said screws, an outlet from said combustion chamber, a motor chamber and a fan chamber in said housing, an inlet into said motor chamber, a motor therein, a dividing wall between said two last mentioned chambers having an opening therein, a shaft extending from said motor, through said opening and supporting a fan thereon in said fan chamber, a duct in said housing leading from said fan chamber and discharging beneath said heater unit in said combustion chamber, and an intake hose having one end free and the other end connected to said inlet.

14. In a detector, a housing having a combustion chamber therein, a heater unit in said combustion chamber, a pair of bimetallic elements in said combustion chamber above said heater unit, a first contact positioned to be engaged by one of said elements when heated, said one element being responsive to a relatively low temperature, the second element being responsive to a relatively higher temperature, a second contact positioned to be engaged by said second element when unheated, a third contact positioned to be engaged by said second element when heated, a duct in said housing leading from said fan chamber and discharging beneath said heater unit in said combustion chamber, and an intake hose having one end free and the other end connected to said inlet.

15. In a detector, a housing having a combustion chamber therein, a heater unit in said combustion chamber, a pair of bimetallic elements in said combustion chamber above said heater unit, one element being responsive to a relatively low temperature, the second element being responsive to a relatively higher temperature, a motor chamber and a fan chamber in said housing, an inlet into said motor chamber, a motor therein, a dividing wall between said two last mentioned chambers having an opening therein, a shaft extending from said motor, through said opening and supporting a fan thereon in said fan chamber, a duct in said housing leading from said fan chamber and discharging beneath said heater unit in said combustion chamber, and an intake hose having one end free and the other end connected to said inlet.

16. The detector of claim 15, said heater unit comprising a ceramic rod having one end thereof screw threaded, an integral ceramic cross rod at the other end of said first mentioned rod, grooves in said cross rod, and a heater wire in said grooves.

17. In a heater unit, a ceramic rod having one end thereof screw threaded, an integral ceramic cross rod at the other end of said first mentioned rod, helical groove means in said cross rod having the axis thereof coincident with the axis of said cross rod, and a heater wire in said groove means.

18. In mine safety apparatus, an electric motor for operating a mining machine, means for supplying power to said motor, control switch means in said power supply means, heat responsive switch means, main circuit means for opening said control switch means upon actuation of said heat responsive switch means in response to a predetermined elevation of the temperature thereof, holding circuit means in parallel with at least part of said main circuit means for maintaining said control switch means in open condition, said main circuit means including means for energizing said holding circuit means upon predetermined actuation of said heat responsive switch means whereby upon initial actuation of said heat responsive switch means said control switch means will be opened and will be held open by said holding circuit means regardless of subsequent temperature changes of said heat responsive switch means.

19. The apparatus of claim 18 and further comprising heater means for said heat responsive switch means including an energizing circuit, said main circuit means including means for opening said heater means energizing circuit upon predetermined actuation of said heat responsive switch means.

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