

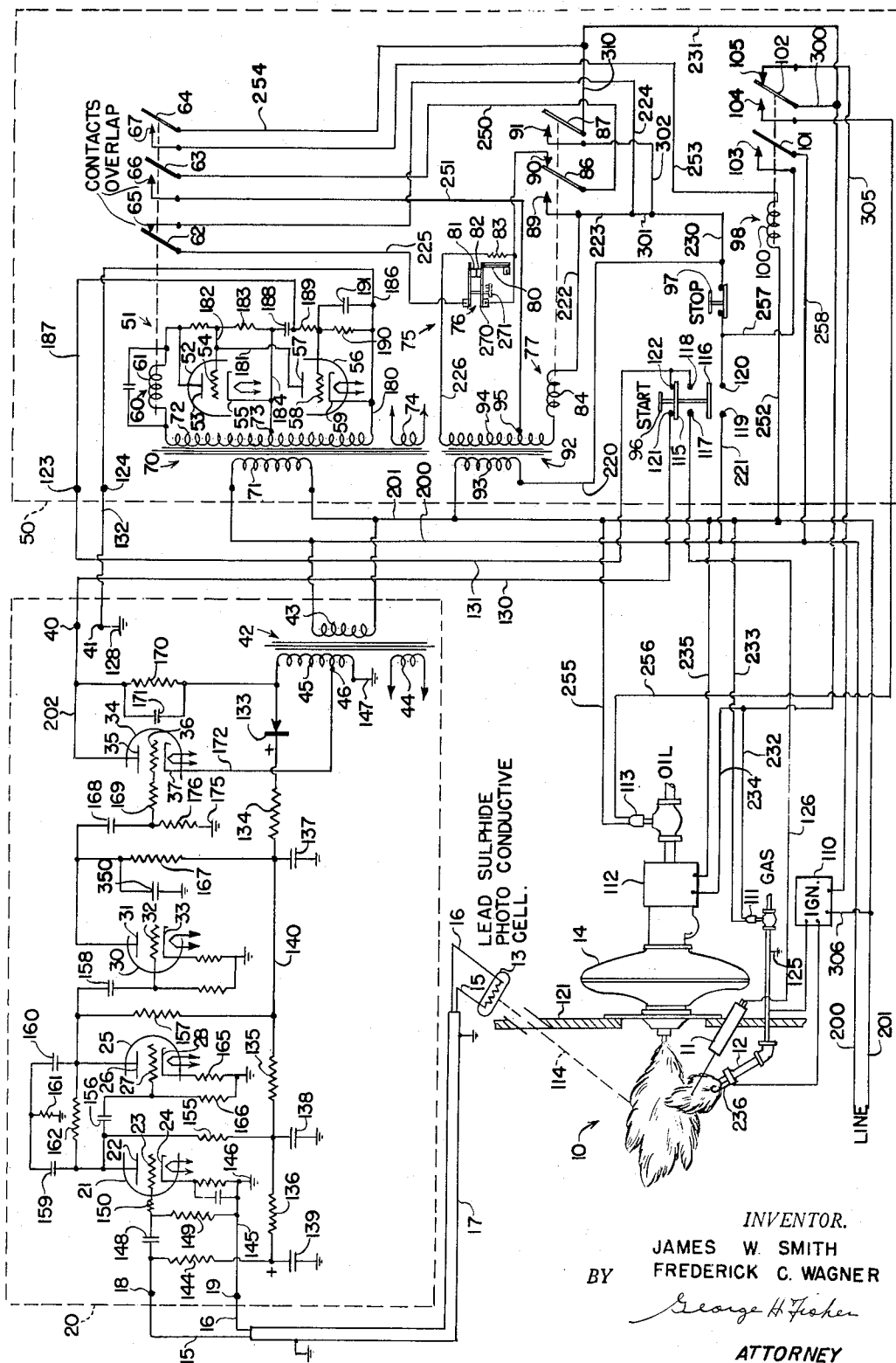
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COMBUSTION SAFEGUARD APPARATUS

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COMBUSTION SAFEGUARD APPARATUS

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The present invention is concerned with an improved type of electronic control for detecting a particular characteristic of a burner flame for sensing the presence of the flame.

The present day flame detectors for the most part detect the presence of flame by making use of the current conducting properties of the flame or making use of the visible electromagnetic wave energy emitted by the flame.

A number of difficulties have arisen in the use of these types of flame detectors. For example, it has been found that when using a conventional flame rod to detect the rectifying properties of the flame the apparatus is limited by practical consideration to the detection of a gas flame. This is true since if a conventional flame rod were used with an oil flame the rod would tend to become covered with carbon formed as a result of burning of the oil and the carbon covered rod would then tend to burn due to the high temperature of the oil flame.

When the flame detector is used with a photo emissive cell to detect the electromagnetic wave energy emitted by a flame it has been found that its use is limited to the detection of an oil flame. This is true since the conventional photo emissive cell, for example the caesium oxide silver cell, is relatively insensitive to the electromagnetic wave energy emitted by a gas flame.

A further problem exists in the use of the photo emissive cell to detect the presence of flame. It has been found that in some applications the fire box associated with a fuel burner becomes heated to an incandescent temperature and radiates a wave energy of constant intensity. Upon a flame failure the photo emissive cell will detect the luminous condition of this fire box when in fact there is no flame present at the oil burner.

It has been found that both oil and gas flame are rich in infra-red radiation and that this radiation fluctuates in intensity at a characteristic rate of from 10 to 30 cycles per second.

The present invention is concerned with a combustion safeguard apparatus making use of a photo electric cell sensitive to the infra-red frequency spectrum so that the apparatus can be used to detect the presence of both gas and oil flame and is sensitive only to infra-red radiations which fluctuate in the characteristic frequency range of a gas or oil flame.

It is an object of the present invention to provide a combustion safeguard having a photo conductive cell which senses the fluctuations in the intensity of wave energy radiated from the flame to be detected and causes a control signal of the characteristic frequency of the intensity fluctuation to be fed to an amplifier which is frequency selective to this characteristic frequency range and which develops a direct current signal indicative of the presence of burner flame to thereby cause energization of a burner control means.

It is a further object of the present invention to provide an adapter unit which, when used in conjunction with a photo conductive cell sensitive to the wave energy radiating from the flame, produces a direct current

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signal of the type normally received from a photo emissive cell or a flame rod, which direct current signal can be applied to the conventional flame detector and thereby adapt the conventional flame detector for detecting the presence of flame by detecting the presence of the fluctuating infra-red wave energy being emitted by the flame.

The single figure is a circuit diagram of the present invention showing a photo conductive cell 13 and an adapter amplifier unit 20 used in conjunction with a conventional type burner control 50 to form a combustion safeguard apparatus.

With reference to the single figure, a gas-piloted horizontal rotary oil burner is shown generally at 10 and a flame rod or rectifying flame sensing assembly 11 is provided to sense the flame being emitted from a gas pilot 12 whereas the lead sulphide photo conductive cell 13 is provided to sense the flame emitted from a horizontal rotary oil burner 14. The photo conductive cell 13 is connected by conductors 15 and 16, which conductors are shielded by a shield 17, to input terminals 18 and 19 of the frequency selective adapter amplifier 20.

An additional feature not shown in the single figure can be used where difficulty is experienced because of the fire box wherein the burner 10 is located being heated to a luminous condition. It has been found that under unusual conditions such as this the cell 13 tends to be saturated. That is, the conductivity value which the cell assumes due to the steady radiation from the fire box is such that the conductivity does not change an appreciable amount due to the fluctuation in intensity of infra-red wave energy being emitted by the flame. In installations such as this it is desirable to allow the cell 13 to sight the burner flame through a small iris-like opening in a shield provided for the cell. This shield and small opening function to limit the quantity of wave energy impinging upon the cell and prevents the saturation of the cell.

The adapter amplifier contains a first amplifying stage having an electron discharge device 21 comprising an anode 22, a control electrode 23 and a cathode 24. A second amplifier stage is provided having an electron discharge device 25 comprising an anode 26, a control electrode 27 and a cathode 28. A further amplifying stage is provided having an electron discharge device 30 comprising an anode 31, a control electrode 32 and a cathode 33.

The adapter amplifier unit 20 is provided with a rectifying output stage having an electron discharge device 34 comprising an anode 35, a control electrode 36, and a cathode 37. The output stage of the amplifier 20 is connected to output terminals 40 and 41 and alternating current power is furnished to the adapter amplifier 20 by means of a transformer 42 having a primary 43, a secondary 44, which provides filament voltages for the filaments of the discharge devices 21, 25, 30 and 34, and having a secondary 45 provided with a tap 46.

A prior art burner control of the type previously used with a flame rod or a photo emissive cell is shown within the broken line 50. This conventional burner control 50 includes an electronic flame detector amplifier unit 51 having a first electron discharge device 52 comprising an anode 53, a control electrode 54 and a cathode 55 and having a second electronic discharge device 56 comprising an anode 57, a control electrode 58 and a cathode 59. The discharge devices 52 and 56 are so interconnected that they are effective to control a relay 60 having a winding 61, movable switch blades 62, 63, and 64, and stationary contacts 65, 66 and 67. The switch blade 62 is normally biased, by means not shown, into engagement with the contact 65 while the switch blades 63 and 64 are normally biased out of engagement with the stationary contacts 66 and 67 respectively. The switch blades 62 and 63 are overlapping, that is, switch blade

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63 engages contact 66 before switch blade 62 disengages contact 65. Alternating current power is furnished to the electronic flame detector 51 by a transformer 70 having a primary 71 and a secondary 72 provided with a tap 73. A second secondary winding 74 is provided to furnish power to the filaments of the electronic discharge devices 52 and 56.

A primary control circuit 75 is shown having a safety cutout device 76 and a control relay 77. The safety cutout device 76 comprises a bimetal actuator 80, normally closed contacts 81 and 82, a bimetal heater 83 and a reset actuator 271. The operation of the cutout device 76 is such that after a predetermined time of energization, the heat from heater 83 causes bimetal 80 to warp to the right thereby causing contacts 81 and 82 to disengage. As will be shown later, this prevents energization of control relay 77. When bimetal 80 again cools a reset button 271 can be depressed and released to reset contacts 81 and 82 to the engaged position.

The relay 77 comprises a relay winding 84, switch blades 86 and 87, and stationary contacts 89, 90 and 91. The switch blade 86 is biased by means not shown to be normally in engagement with the stationary contact 90 and disengaged from the stationary contact 89. The switch blade 87 is biased to normally be disengaged from the stationary contact 91. Alternating current power is furnished to the control circuit 75 by means of a transformer 92 having a primary 93 and a secondary 94 having a tap 95.

The burner control apparatus includes a start button 96 and a stop button 97. Also associated with the burner control apparatus is a relay 98 having a relay winding 100, movable switch blades 101 and 102, and stationary contacts 103, 104 and 105. The switch blade 102 is biased by means not shown to be normally in engagement with the stationary contact 105 and to be normally disengaged from the stationary contact 104. The switch blade 101 is biased to normally be disengaged from the stationary contact 103.

The relays 60, 77 and 98 of the burner control apparatus 50 along with their associated switch blades and stationary contacts are so interconnected as to cause an ignition transformer 110 and pilot valve 111 associated with the pilot burner 12, and a burner motor 112 and oil valve 113 associated with the rotary oil burner 14 to be operated in a predetermined manner in accordance with the condition of the relays 60, 77 and 98, with the entire burner control apparatus 50 being under the control of the start button 96 and the stop button 97.

It has been found desirable in gas-pilot oil-fired burner installations to have the photo conductive cell 13 sense the main oil flame at a substantial portion of the flame as indicated by the dotted line 114. It can be readily seen that with the photo conductive cell 13 in this position, the photo conductive cell is unable to detect the gas flame emitted from the pilot 12. Therefore, it is necessary to provide the flame rod assembly 11 to sense the gas flame emitting from the pilot burner 12.

As is well known, the flame of a burner has an electrical conductivity characteristic which is greater in one direction than in the other. In other words, an alternating source of power when supplied to the pilot burner 12 and the flame rod assembly 11 will be rectified by the pilot flame since the characteristic of the flame is such that electron current will flow more readily from the pilot burner 12 through the flame to the flame electrode. A rectified direct current signal is thereby obtained as an indication of the presence of pilot burner flame.

In a number of applications it has been found, as before-mentioned, that the heat given off by the main burner flame has heated the associated fire box, represented in part as 121 of the single figure, to be incandescent in character and in some extreme cases it has been found that it is impossible to visually detect a flame against the incandescent fire box. It has therefore become neces-

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sary to employ a type of flame sensing means which would not be affected by the steady state luminous energy radiated by the fire box since an unsafe condition would surely arise if the flame sensing means detected the luminous energy radiated by the fire box to indicate that burner flame was present when in fact the burner flame may have been extinguished. With a photo electric cell connected to detect steady state luminous energy, flame would continue to be detected after the flame has in fact been extinguished until the fire box had cooled to a point where it no longer radiates luminous energy to the conventional photo emissive cell.

It has been found that a common characteristic exists between gas and oil flames in that the wave energy emitted by the flames fluctuates in a characteristic frequency band which has been found to lie substantially within the range from 10 to 30 cycles per second. The greater portion of this wave energy exists in the infra-red frequency spectrum and the conventional photo emissive cell is not sensitive to the infra-red frequency spectrum. It is therefore necessary to employ a flame sensing device such as a lead sulphide photo conductive cell which is sensitive to infra-red wave energy and which varies in conductivity with the characteristic fluctuations in the intensity of the infra-red wave energy being radiated by the flame, which as before-mentioned lies in the frequency range from 10 to 30 cycles per second. This lead sulphide photo conductive cell when viewing the flame therefore causes a fluctuating signal voltage of from 10 to 30 cycles per second to be generated when the lead sulphide cell is connected to an energizing source, for example, a series connected load resistor and direct current source of power as shown in the present invention, to be explained later.

To properly supervise the burner as shown in the single figure, it is therefore necessary to provide a burner control apparatus which will sense the direct current signal supplied by the flame rod assembly 11 and which will detect the fluctuating control signal supplied by the photo conductive cell 13. This is accomplished as follows.

The start button 96 of the conventional burner control 50 is provided with a shorting bar 115 and a shorting bar 116 which, when the start button 96 is depressed, completes a circuit from a stationary contact 117 to a stationary contact 118 and completes a second circuit from a stationary contact 119 to a contact 120 respectively. The normal position of the shorting bar 115 is such that connection is made from a stationary contact 121 to a contact 122. As will be explained later, the sequence of operations is such that depressing the start button causes the ignition transformer 110 and the pilot valve 111 to be energized and also completes a circuit from the flame rod assembly 11 to input terminals 123 and 124 of the control apparatus 50. This last-named circuit can be traced from a ground connection 125 through the pilot burner assembly 12, pilot flame, flame rod assembly 11, a conductor 126, stationary contact 117, shorting bar 115, stationary contact 118, conductor 131, input terminal 123 and input terminal 124 of burner control 50, conductor 132, and output terminal 41 of the adapter amplifier unit 29 to a ground connection 123. At the same time the shorting bar 115 breaks the normally closed circuit from the stationary contact 121 to the contact 122 and the opening of this circuit disconnects the output terminal 40 of the adapter amplifier unit 20 from the input terminal 123 of the control apparatus 50.

The apparatus 50 is now conditioned to detect the pilot flame and upon the pilot flame being detected the operator releases the start button to disconnect the flame rod assembly 11 from the input terminals of the burner control apparatus 50 and to connect the output of the adapter amplifier unit 29 to the input of the control apparatus 50. This circuit can be traced from the output terminal 40 of the adapter amplifier 29 through con-

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ductor 130, stationary contact 121, shorting bar 115, stationary contact 122, conductor 131, input terminals 123 and 124 of the control apparatus 50, and conductor 132, to output terminal 41. It can therefore be seen that the control apparatus 50, through the adapter amplifier 20, is conditioned to sense the main oil flame by means of the photo conductive cell 13. The nature of the adapter amplifier 20 is such that a fluctuating signal applied to the input terminals 18 and 19 lying within a predetermined frequency range of from 10 to 30 cycles per second will cause a direct current signal voltage of the same order of magnitude as that supplied by flame rod 11 to appear at the output terminals 40 and 41, which direct current signal voltage when applied to the input terminals 123 and 124 of the control apparatus 50 is effective to cause the electronic flame detector 51 to assume a condition indicative of the presence of the oil flame.

Operation of the adapter amplifier 20

It is desirable to present a detailed explanation of the adapter amplifier 20 at this point in the discussion of the present invention. As before-mentioned, upon a flame existing at the rotary oil burner a fluctuating signal voltage is applied to the input terminals 18 and 19 of the adapter amplifier 20 and this at this point in the discussion of the present invention. As before-mentioned, upon a flame existing at the rotary oil burner a fluctuating signal voltage is applied to the input terminals 18 and 19 of the adapter amplifier 20 and this fluctuating signal voltage lies within the predetermined frequency range of from 10 to 30 cycles per second. It is to be noted at this point that due to pick-up in the lead wires 15 and 16 extending from the unit 20 to the photo conductive cell 13 other signal voltages may be present. However, the signal voltages which are within the above-mentioned predetermined frequency range are the only signal voltages which affect amplifier unit 20, as fully explained below.

A direct current source of power is supplied within the adapter amplifier 20 to furnish power to the first, second, and third amplifier stages and to the photo conductive cell 13. This direct current source of power comprises a selenium rectifier 133 connected to the secondary 45 of the transformer 42 to supply a direct current source of voltage of the polarity indicated in the drawing to be a three-section, L-type RC filter comprising resistors 134, 135, 136 and capacitors 137, 138 and 139. A circuit for supplying a direct current voltage to the photo conductive cell 13 can be traced from the extreme position terminal of the filter network through a load resistor 144, input terminal 18, conductor 15, photo conductive cell 13, conductor 16, input terminal 19, conductor 145, and ground connection 146 to ground connection 147 associated with the lower terminal of the secondary 45.

It can thereby be seen that fluctuations in the conductivity of the photo conductive cell 13 will cause a fluctuating direct current signal to be developed across the load resistor 144. This fluctuating signal is applied through a blocking capacitor 148 and a grid resistor 149 to the input of the discharge device 21. A low pass filter is associated with this electronic discharge device 21 and comprises a resistor 150 in conjunction with the input impedance of the discharge device 21. In a manner well known in the art the combination of this resistor 150 and the input admittance of the discharge device 21 can be adjusted by selecting proper values of the resistor 150 to allow frequencies lying only below a given frequency to effect the input of the discharge device 21. In this manner high frequency signals picked up by conductors 15 and 16 are prevented from effecting the discharge device 21.

The anode 22 of the discharge device 21 is connected through a plate load resistor 155 to the direct current source of power and the amplified fluctuating signal voltage developed across the load resistor 155 is applied through a blocking capacitor 156 to the input of the

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discharge device 25. The anode 26 of the discharge device 25 is connected through a plate load resistor 157 to the direct current source of power and the amplified fluctuating signal voltage developed across the plate load resistor 157 is applied through a blocking capacitor 158 to the control electrode 32 of the discharge device 30.

A bridged T null network is provided to give frequency selective degenerative feedback from the output of the discharge device 25 to the input of the discharge device 25. This bridged T null network comprises a first capacitive leg 159, a second capacitive leg 160 and a third resistive leg 161. A bridging resistor 162 is provided and bridges the capacitive legs 159 and 160. It will be noted that the cathode 28 of the discharge device 25 is connected through a cathode resistor 165 to ground or reference potential while the control electrode 27 is connected through a resistor 166 to the reference potential. The above-mentioned bridged T null network has the first capacitive leg 159 connected through the blocking capacitor 156 to the control electrode 27 while the second capacitive leg 160 is connected directly to the anode 26. The third resistive leg 161 of the bridged T null network is connected to ground or reference potential and the bridging resistor 162 is connected from the anode 26 through the blocking capacitor 156 to the control electrode 27.

The inherent characteristics of this bridged T null network are such that a substantial degenerative signal is fed from the anode circuit of the discharge device 25 to the control electrode circuit of this discharge device for all frequencies except that range of frequencies lying within the null frequency range of the bridged T null network. The values of the components making up the bridged T null network have been selected such that its null frequency lies in the band of from 10 to 30 cycles per second and therefore this second amplifier stage is greatly degenerative to all signals not lying within the frequency range from 10 to 30 cycles per second. Therefore, for all practical purposes only signal voltages which lie in the frequency range from 10 to 30 cycles per second will be applied to the control electrode 32 of the discharge device 30. In one particular embodiment, it was found desirable to use components having the following values for the bridged T null network:

Resistor 161-----ohms--	220,000
Resistor 162-----do----	10,000,000
Capacitors 159 and 160-----microfarads--	0.01

The anode 31 of the discharge device 30 is connected through a plate load resistor 167 to the direct current source of power, and through the blocking capacitor 168 and a resistor 169 to the control electrode 36 of the discharge device 34. A by-pass capacitor 350 is associated with plate load resistor 167. This capacitor 350 in conjunction with the plate resistance of the discharge device 30 forms a low pass filter which aids the above-mentioned bridged T null network in determining the frequency selective characteristics of the amplifier unit 20. The anode 35 of the discharge device 34 is connected through a plate load impedance comprising a parallel resistor 170 and capacitor 171 network to the upper terminal of the secondary 45 of the transformer 42. The cathode 37 of the discharge device 34 is connected through conductor 172 to the tap 46 of the secondary 45 and the control electrode 36 is connected through resistor 169 and a resistor 176 to ground potential at ground connection 175. It can be seen that the voltage from the control electrode 36 to the cathode 37 is of opposite phase to the voltage from the anode 35 to the cathode 37 of the discharge device 34. The value of voltage has been selected so that the discharge device 34 is substantially at cut-off with no signal applied to the control electrode 36; in other words, when the anode 35 of the discharge device 34 is positive with respect to the cathode 37 the control electrode 36 is sufficiently negative with respect to the cathode 37 so that anode current will not

flow in the absence of a positive control signal applied to control electrode 36. This output stage of the adapter amplifier unit 20 will therefore be of a rectifying type since anode current flows only when a positive control signal is applied to the control electrode and this current will flow only when the anode 35 is positive with respect to the cathode 37.

In a manner well known in the art, grid rectification of the alternating current bias voltage in a circuit of this type causes the device 34 to have its greatest sensitivity to input signals of the power line frequency. Since it is not desirable to detect the power frequency, it is desirable to reduce the sensitivity of the device 34 to this power frequency by the provision of a resistor 169. Resistor 169 reduces the sensitivity of device 34 to signals of the power line frequency by reducing the rectification of the alternating current bias voltage.

Assume a flame is now detected by the photoconductive cell 13: a signal voltage within the frequency range of from 10 to 30 cycles per second will be applied to the input electrode 36 of the discharge device 34 and the discharge device 34 will conduct on the positive half cycles of this input signal voltage which occur when the anode 35 is positive. This rectified signal flowing through the plate load resistor 170 causes the capacitor 171 to be charged in such a polarity as to supply a negative direct current voltage to the output terminal 40 and to supply a positive voltage through the secondary 45 of the transformer 42, ground connection 147 and the ground connection 123 to the output terminal 41. By virtue of the time constant of resistor 170 and capacitor 171 this voltage at the output terminals 40 and 41 is retained during the half cycle that anode 35 is negative with respect to cathode 37.

Operation of the burner control 50

The electronic flame detector 51 is of the type wherein the discharge device 56 is normally conducting to bias the discharge device 52 to cut-off and thereby prevent the energization of the relay 60. This can be shown by tracing the conduction circuit for the discharge device 56 from the lower terminal of the secondary 72 through conductor 180, cathode 59, anode 57, conductor 131, conductor 182, resistor 183, and conductor 184 to the tap 73 of the secondary 72. The voltage developed across the resistor 183 is effective to bias the discharge device 52 to cut-off and the relay 60 will thereby remain deenergized. If a rectifying impedance such as the flame rod assembly 11 is connected to the input terminals 123 and 124 of the burner control 50 when flame is present at the pilot burner 12 a biasing voltage will be developed for the discharge device 56 such that the device is cut off. Assume that the start button is depressed so that the flame electrode assembly 11 is connected to the control apparatus 50 through a circuit which can be traced from the lower terminal of the secondary 72 through the conductor 186, input terminal 124 of burner control 50, conductor 132, output terminal 41 of amplifier 20, ground connection 123, ground connection 125, pilot burner assembly 12, the pilot flame, flame rod assembly 11, conductor 126, stationary contact 117, shorting bar 115, stationary contact 118, conductor 131, input terminal 123, conductor 187, capacitor 188, and conductor 184 to the tap 73 of the secondary 72. It can be seen that the direction of conduction through the pilot flame will charge the capacitor 188 such that its lower plate will be negative and the upper plate will be positive. This charge on the capacitor is redistributed through a resistor 189 to a filter network comprising a parallel resistor 190 and capacitor 191 to place a charge on the capacitor 191 which is effective to bias the discharge device 56 to cut-off. With the discharge device 56 biased to cut-off the voltage developed across the resistor 183 in its anode circuit no longer exists and the discharge device 52 is then conductive to energize the relay 60.

Assume now that the start button has been released and that an oil flame is established and detected by the photoconductive cell 13. In the manner before-described, the adapter amplifier unit 20 converts the fluctuating signal voltage received from the photoconductive cell 13 to a direct current voltage and supplies this voltage to the output terminals 40 and 41 of the adapter unit 20, with the terminal 40 being negative with respect to the terminal 41. With the start button released the positive terminal 40 is connected through conductor 130, stationary contact 121, shorting bar 115, stationary contact 122, conductor 131, input terminal 123, conductor 187, and resistor 189 to the control electrode 58 of the discharge device 56. The cathode 59 of the discharge device 56 is connected through the conductor 186, input terminal 124, and conductor 132 to the positive output terminal 41 of the adapter unit 20. Therefore it can be seen that the direct current output voltage of the adapter amplifier unit 20 is effective to bias the discharge device 56 of the electronic flame detector 51 to cut-off and as before-described to cause the relay 60 to be energized.

Operation of the combustion safeguard apparatus

It will first be assumed that the stop button 97 has been depressed and then released so that a flame does not exist at the pilot burner 12 or the rotary oil burner 14. The primary 43 of the transformer 42 is connected to power lines 200 and 201 and therefore the filaments of the discharge devices 21, 25, 30 and 34 are energized and the photoconductive cell 13 has a direct current voltage applied thereto. Likewise, the primary 71 of the transformer 70 is connected to the power lines 200 and 201 and the filaments of the discharge devices 52 and 56 are energized. However, as before-described the discharge device 52 is biased to cut-off and the relay 60 is deenergized. The relay 77 associated with the control circuit 75 is deenergized and the relay 98 is likewise deenergized.

In order to initiate operation of the rotary oil burner 14 it is necessary for an operator to manually depress the start button 96 and to maintain the start button depressed until a flame is established at the pilot burner 12. Depressing the start button 96 first causes the primary 93 of the transformer 92 to be energized. The energizing circuit can be traced from the power supply line 201 to the upper terminal of the primary 93, the lower terminal of primary 93, conductor 220, stop button 97, stationary contact 120, shorting bar 116, stationary contact 119, and conductor 221 to the power supply line 200. With the transformer 92 now energized the relay 77 is energized by means of a circuit which can be traced from the lower terminal of the secondary 94 through relay winding 84, conductor 222, conductor 223, conductor 224, stationary contact 65 and movable switch blade 62 of relay 60, conductor 225, safety cut-out contacts 81 and 82, safety cut-out heater 83, and conductor 226 to the upper terminal of the transformer secondary 94.

Energization of the relay winding 84 of relay 77 causes the switch blades 86 and 87 to move to their actuated positions. Movable switch blade 86 engages contact 89 to complete a portion of a holding circuit for relay 77. Movable switch blade 87 engages fixed contact 91 to complete an energizing circuit for the pilot valve 111, the rotary oil burner blower motor 112 and the ignition transformer 110. The energizing circuit for valve 111 and motor 112 can be traced from the power line 200 through conductor 221, stationary contact 119, shorting bar 116, stationary contact 120, stop button 97, conductor 230, conductor 302, contact 91 and switch blade 87 of relay 77, conductor 310, conductor 231, conductors 232 and 234 to the pilot valve 111 and blower motor 112 respectively and conductors 233 and 235 from the pilot valve 111 and blower motor 112 respectively, to the power line 201. The energizing circuit for the ignition transformer 110 can be traced from the power line 200

through conductor 221, stationary contact 119, shorting bar 116, stationary contact 120, stop button 97, conductor 230, conductor 302, contact 91 and switch blade 87 of relay 77, conductor 310, conductor 231, conductor 300, switch blade 102 and contact 105 of relay 98, conductor 305, ignition transformer 110, and conductor 306 to power line conductor 201. With the pilot valve 111 open, gas flows to the pilot burner 12 and is ignited by means of the spark electrode 236 connected to the ignition transformer 110.

The flame electrode assembly 11 detects the pilot flame and in a manner before-described a direct current signal is developed at the electronic flame detector 51 such that the relay 60 is energized. The switch blades 62, 63 and 64 are moved to their actuated positions by the energization of relay 60. The switch blades 62 and 63, as before-mentioned, overlap in their operation, that is, the switch blade 63 makes connection with the stationary contact 66 before the switch blade 62 disengages the switch contact 65. The engagement of switch blade 63 with contact 66 completes the before-mentioned holding circuit for the relay 77 which is independent of the safety cut-out device 76. This holding circuit can be traced from the lower terminal of the secondary 94 through relay winding 84, conductor 222, switch contact 89 and movable switch blade 86, conductor 250, switch blade 63 and contact 66, and conductor 251 to the tap 95 of the transformer secondary 94. The disengaging of the switch blade 62 from the contact 65 opens the energizing circuit for the bimetal heater 83 of the safety cut-out device 76 and this heater 83 will remain deenergized so long the electronic flame detector 51 energizes the relay 60 to keep the switch blade 62 disengaged from the contact 65.

The engagement of the switch blade 64 with the stationary contact 67 completes an energizing circuit for the relay 98. This energizing circuit can be traced from the supply line conductor 201 through conductor 252, relay winding 100, conductor 253, contact 67 and movable switch blade 64, conductor 254, conductor 310, movable switch blade 87 and stationary contact 91, conductor 302, conductor 230, stop button 97, contact 120, shorting bar 116, contact 119, and conductor 221 to the supply line conductor 200. The energization of relay 98 actuates the movable switch blades 101 and 102 to their energized positions. The movable switch blade 101 makes contact with the stationary contact 103 to complete a holding circuit around the start button 96 and the movable switch blade 102 makes connection with the stationary contact 104 and disengages the stationary contact 105 to deenergize the ignition transformer 110 and to energize the oil valve 113. The energizing circuit for the oil valve 113 can be traced from the supply line conductor 201 through conductor 255, oil valve 113, conductor 256, contact 104 and movable switch blade 102, conductor 231, conductor 310, movable switch blade 87 and stationary contact 91, conductor 302, conductor 230, stop button 97, conductor 257, stationary contact 103 and movable switch blade 101, and conductor 258 to the supply line conductor 200. The operator may now release the start button 96 and an oil flame will normally be established at the rotary oil burner 14.

The photo conductive device 13 is effective to detect the characteristic fluctuations in the oil burner flame and in the manner before-described a direct current signal is supplied from the output of the adapter amplifier unit 20 through the contacts 121 and 122 of the start button to the burner control apparatus 50 and the electronic discharge device 51 is conditioned to maintain the relay 60 energized unless there is a subsequent flame failure at the rotary oil burner 14.

Assume now that the oil flame established by the rotary oil burner in the manner above-described is accidentally extinguished. The photo conductive device 13 no longer senses the characteristic fluctuations in the infra-red wave energy being emitted by the flame and as a result the

adapter amplifier unit 20 does not develop a direct current voltage at the output terminals 40 and 41. If at this time the fire box is heated to an incandescent state, the amplifier unit 20 does not develop a direct current voltage at its output terminal because these incandescent radiations of the fire box are not fluctuating in intensity. It is important to note at this point that the input circuit of unit 20 which includes the lead wires leading from the photo conductive device 13 to the input terminals 18 and 19 of the adapter amplifier unit 20, does pick up interference which presents a signal to the control electrode 23 of device 21. However, because of the above-described low pass filter associated with the electronic discharge device 21 and the bridge T null network which gives the second stage of the amplifier frequency selective characteristics identical to the characteristic fluctuations of a flame, the radiations picked up by the lead wires to the photo electric device 13 do not pass to the rectifier output stage of the amplifier 20 to produce a direct current voltage at the output terminals 40 and 41.

A condition now exists where a direct current voltage is not supplied to the input terminals 123 and 124 of the control apparatus 50 and the electronic flame detector 51 in the manner above-described deenergizes the relay 60. The switch blades 62, 63 and 64 therefore return to the positions shown in the single figure. The disengaging of switch blade 64 from the stationary contact 67 opens the energizing circuit for the relay 98. The deenergization of the relay 98 causes its switch blades 101 and 102 to assume their positions shown in the single figure. The disengaging of switch blade 101 from the stationary contact 103 opens the energizing circuit from the power line 200 to the control apparatus 50 and thereby deenergizes the entire burner system. The burner system is now safely shut down and it is necessary for the operator to again depress the start button to initiate operation of the burner system in the manner above-described.

Assume that the operator again depresses the start button 96. The motor 112, ignition transformer 110 and the pilot valve 111 will be again energized in the manner above-described to normally establish a flame at the pilot burner 12. If a flame is not established at the pilot burner 12 the electronic flame detector 51 will not energize the relay 60 and the holding circuit for the relay 77 will not be established, the relay 77 remaining energized through the above-traced circuit which includes the safety cut-out heater 83. After a predetermined length of time the safety cut-out heater 83 is effective to warp the bimetal 80 to the right and when the bimetal 80 has warped out from under blade 270 the contact 82 disengages the contact 81. This causes the relay 77 to be deenergized and the switch blades 86 and 87 of the relay 77 assume the position shown in the single figure. Disengaging of the movable switch blade 87 with the contact 91 deenergizes the ignition transformer 110, the pilot valve 111, and the rotary oil burner motor 112.

The opening of the safety cut-out contacts 81 and 82 also deenergizes the safety cut-out heater 83 and after a predetermined length of time the bimetal 80 will cool. The operator may then depress the reset actuator 271 to reset the safety cut-out contacts 81 and 82. He may then again depress the start button 96 to make a further attempt to establish combustion.

If a flame is established as the oil burner 14 on this attempt it is necessary to depress stop button 97 to turn off the oil burner. Depressing of stop button 97 breaks the energizing circuit from the power line 200 to the burner control 50 and the entire burner system is thereby deenergized.

Assume now that a fault has occurred in the electronic flame detector 51 such that relay 60 is not deenergized in response to the absence of flame at the oil burner 14. The relay 77 will have been deenergized when the stop button 97 was depressed and the switch blades 86 and 87 will be at the position shown in the single figure.

With the burner control 50 in this condition, the heater 83 of the safety cut-out 76 is energized by means of a circuit which can be traced from the upper end of transformer 94 through conductor 226, heater 83, contact 99 and switch blade 86 of relay 77, conductor 230, switch blade 63 and contact 66 of relay 69, and conductor 251 to the tap 95 of secondary 94. The safety cut-out 76 will therefore be actuated and contacts 81 and 82 will disengage. However, the heater 83 will remain energized until the fault within the electronic flame detector 51 is corrected and depressing of the reset actuator 271 will not reset the safety cut-out contacts 81 and 82 until the fault has been corrected and bimetal 30 has subsequently cooled.

It can therefore be seen that we have shown an improved burner control apparatus wherein an adapter amplifier unit is used to adapt the conventional flame detector such that the conventional flame detector can be used to detect characteristic fluctuations in the wave energy being emitted by a flame.

We claim as our invention:

1. A combustion safeguard for use with a pilot burner and a main burner which supports a flame having electromagnetic wave energy radiating therefrom in the infra-red range and fluctuating in intensity within a given frequency range when fuel is supplied thereto comprising, a photo conductive cell sensitive to infra-red radiation, for sensing the presence of flame at the main burner by sensing the fluctuation in the intensity of the flame, a source of direct current power, a load impedance, means connecting said photo conductive cell, said source of direct current power and said load impedance in a series circuit so that when said photo conductive cell is subjected to the infra-red radiation of a flame at the main burner the voltage developed across said load impedance is an alternating current voltage within said given frequency range; a first amplifier unit having an input circuit and an output circuit including burner control means, said first amplifier unit being arranged to energize said burner control means only when a direct current voltage is supplied to said input circuit; a second frequency selective amplifier unit having feedback means connected to render said second amplifier sensitive to the given frequency range of fluctuation in the infra-red wave energy radiated from the main burner, said second amplifier unit having an input stage, an intermediate stage and a rectifying output stage; means connecting said load impedance to the input stage of said second amplifier unit to thereby apply said alternating current voltage to said input stage when said photo conductive cell is subjected to the infra-red radiation of a flame, the rectifying output stage of said second amplifier unit rectifying said alternating current voltage to produce a direct current voltage; rectifying flame sensing means adapted to be arranged to sense a flame at the pilot burner, and two position switching means, said switching means when in a first position connecting the input circuit of said first amplifier unit to said rectifying flame sensing means and when in the second position connecting the input circuit of said first amplifier unit to the rectifying output stage of said second amplifier unit.

2. An adapter unit for use with a separate flame detector unit which normally utilizes a rectifying means sensitive to flame for detection and which requires a direct current signal in order for the flame detector to sense the presence of flame at a burner, which flame has infra-red wave energy emitting therefrom fluctuating in intensity within a given frequency range, comprising, a photo conductive cell sensitive to the infra-red wave energy which cell varies in conductivity in response to fluctuations in infra-red wave energy impinging upon said cell, a source of direct current power, a first load impedance, means connecting said power source, said first load impedance and said photo conductive cell in a series circuit whereby an alternating current voltage is

developed across said first load impedance when fluctuating infra-red wave energy impinges upon said photo conductive cell; an amplifier having a plurality of electronic stages, means connecting said first load impedance to the input of said amplifier, a low pass filter associated with the input of said amplifier and arranged to pass all input signal voltages below a given frequency to the intermediate stages of said amplifier, a null network associated with an intermediate stage of said amplifier and arranged to cause substantial degeneration of all input signal voltages passed to said intermediate stage which do not lie in a given frequency range, said frequency range being substantially the same as the frequency range of the fluctuation in intensity of infra-red wave energy emitted by the flame at the burner; an output stage including an electronic discharge device having an anode, cathode and control electrode, an alternating current source of power having a pair of end terminals and a tap, said tap being at a potential level between said end terminals, a second load impedance, means connecting one end terminal of said alternating current source through said second load impedance to said anode, means connecting said tap to said cathode, means connecting the other of said end terminals to said control electrode to thereby substantially bias said electronic discharge device to cut-off, said output stage producing a direct current voltage across said second load impedance when the positive portion of a signal voltage is applied to said control electrode, and means connecting said second load impedance to the flame detector unit.

3. An adapter unit for use with a separate flame detector unit which normally utilizes the rectifying properties of a flame for detection and which requires a direct current signal voltage in order for the flame detector unit to sense the presence of flame, comprising, photoelectric means sensitive to the characteristic fluctuations in intensity of electromagnetic wave energy emitted by a flame to supply an alternating current signal indicative of the presence of flame, a multistage electronic amplifier having an input circuit and a plurality of stages including a rectifying output stage connected to output terminals, one of said stages including an electron discharge device having an input electrode and an output electrode, null network means associated with said one of said stages of said amplifier and connected from said output electrode to said input electrode to provide feedback in a sense which renders said amplifier frequency selective to only a range of frequencies which includes said characteristic fluctuation of a flame, and means connecting said photoelectric means to the input of said amplifier, the output stage of said amplifier thereby supplying a direct current voltage indicative of the presence of flame to said output terminals when said photoelectric means is exposed to a flame.

4. A combustion safeguard for use with a fuel burner which supports a flame having wave energy radiating therefrom in the infra-red range and fluctuating in intensity in a given frequency range, comprising, an amplifier unit having a first and a second input terminal and having an output stage with burner control means actuated thereby when a direct current voltage of a given polarity is applied to said input terminals, a first alternating current source of power, circuit means including said first source of power connected to said input terminals to supply alternating current power to said input terminals; a photo conductive cell sensitive to infra-red wave energy, which cell varies in conductivity in accordance with the fluctuation in intensity of infra-red wave energy impinging upon said cell, an adaptor amplifier unit having null network means connected in a feedback circuit to render said second amplifier unit frequency selective to only frequencies substantially the same as the given frequency range of fluctuation of the infra-red wave energy emitted by a burner flame, input terminals for said adaptor amplifier unit, means connecting said photo conductive cell to the

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input terminals of said adaptor amplifier unit to thereby supply to said input terminals a fluctuating signal voltage when said photo conductive cell is exposed to a burner flame; said adaptor amplifier unit having an output stage including an electron discharge device having an anode, cathode and control electrode, a second alternating current source of power, load impedance means, means connecting said second alternating current source of power through said load impedance to the anode and cathode of said discharge device, means connecting said second alternating current source of power to the control electrode and cathode of said discharge device so as to substantially bias said discharge device to cut-off to thereby produce a direct current voltage across said load impedance only when the positive portion of the fluctuating signal voltage is applied to said control electrode; and means connecting said load impedance to said input terminals of said first amplifier to thereby apply a direct current voltage of said given polarity to said input terminals of said first amplifier when said photo conductive cell is subjected to the fluctuating infra-red wave energy being emitted by a burner flame.

5. A combustion safeguard for use with a fuel burner having a pilot burner located in igniting relation thereto, comprising, a flame detector amplifier having input terminals and an output circuit including a burner control means rendered operable when a direct current signal is supplied to said input terminals; means sensitive to the rectifying properties of a flame to produce a direct current signal, said last named means being adapted to be associated with one of the burners; means sensitive to the

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electromagnetic wave energy radiated by a flame to produce an alternating current signal in accordance with the characteristic fluctuation in intensity of said wave energy, said last named means being adapted to be associated with the other of the burners; a frequency selective adaptor amplifier having feedback means connected to render said adaptor amplifier sensitive only to the characteristic fluctuation in intensity of the wave energy radiated by a flame, said adaptor amplifier also having input and output terminals and arranged to supply a direct current signal to said output terminals when an alternating current signal characteristic of said fluctuation of the wave energy emitted by a flame is supplied to said input terminals; means connecting said means sensitive to the electromagnetic wave energy of a flame to the input terminals of said adaptor amplifier, and switching means arranged to selectively connect said means sensitive to the rectifying properties of a flame and the output terminals of said adaptor amplifier to the input terminals of said flame detector.

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