Oct. 26, 1954 E. C. THOMSON 2,692,962

FLAME-FAILURE SAFEGUARD APPARATUS

Filed March 27, 1952 3 Sheets-Sheet 1

FIG. 1

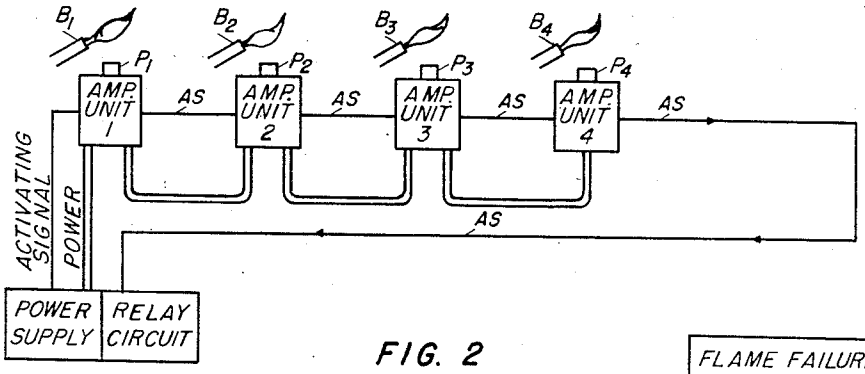


FIG. 2

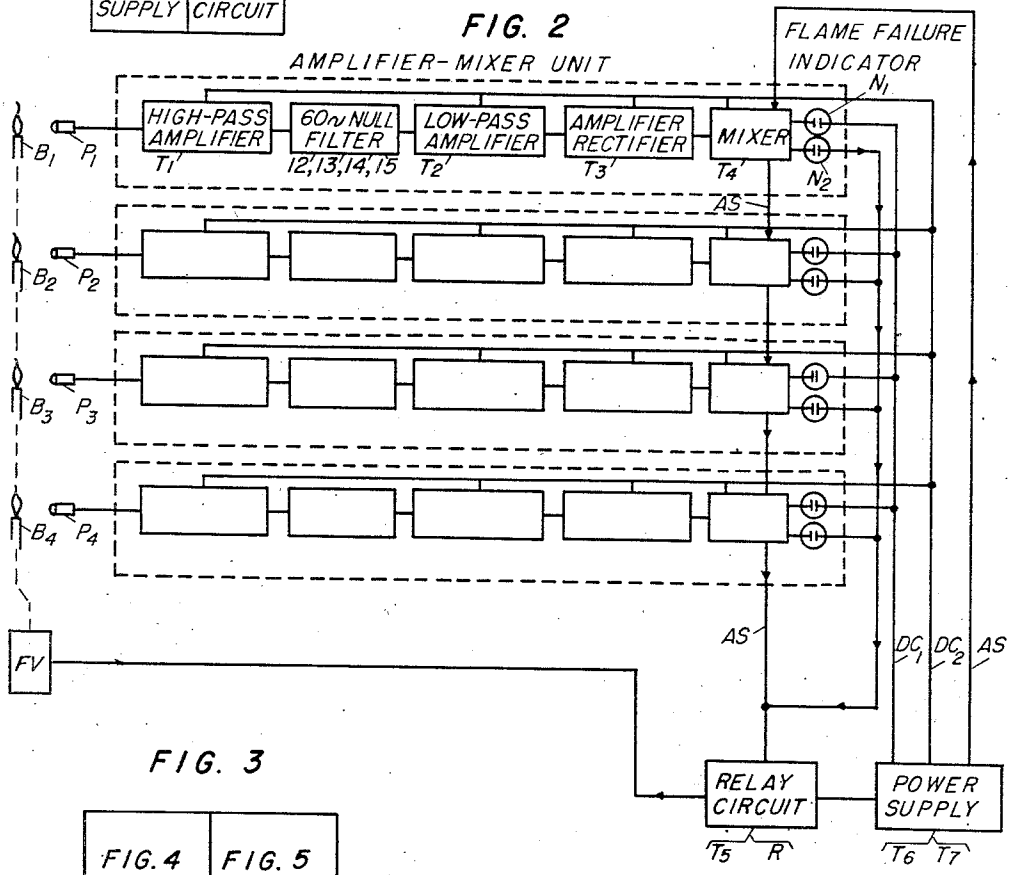
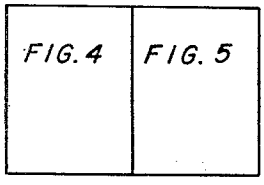


FIG. 3



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FLAME-FAILURE SAFEGUARD APPARATUS

Filed March 27, 1952 3 Sheets-Sheet 2

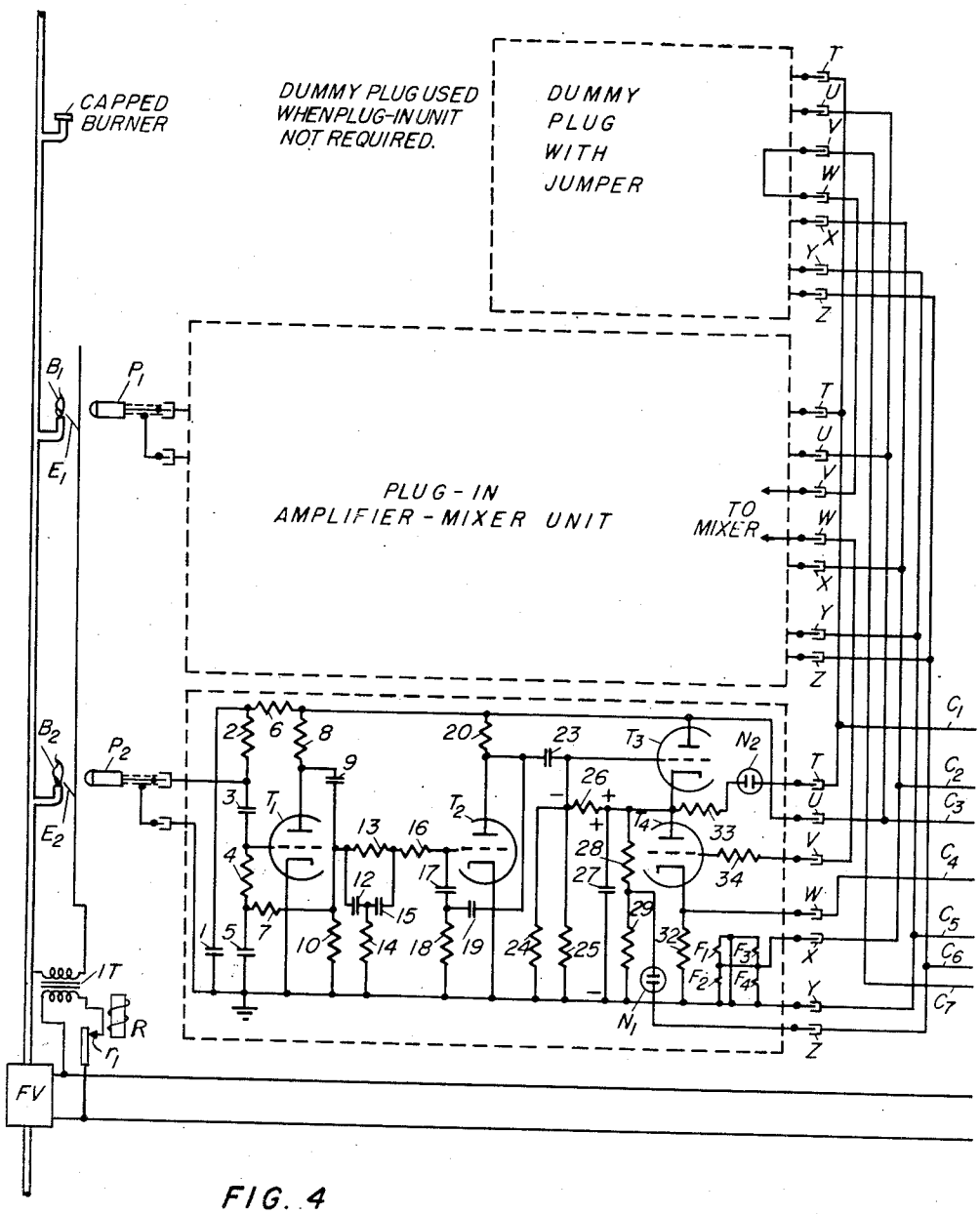


FIG. 4

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FLAME-FAILURE SAFEGUARD APPARATUS

Filed March 27, 1952 3 Sheets-Sheet 3

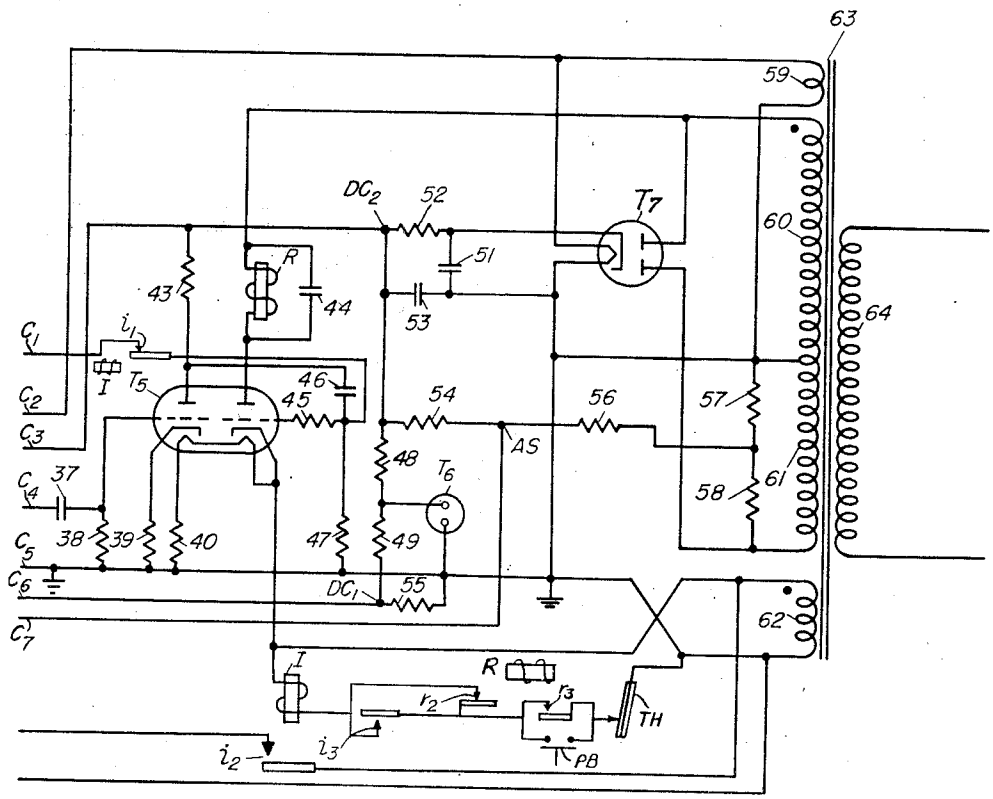


FIG. 5

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UNITED STATES PATENT OFFICE

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FLAME-FAILURE SAFEGUARD APPARATUS

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Application March 27, 1952, Serial No. 278,903

3 Claims. (Cl. 317—130)

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This invention relates to new and improved control apparatus for supervising the flames of multi-burner heating systems.

An object of this invention is to improve the operative reliability of flame-failure safeguard apparatus for multi-burner heating systems.

Another object of this invention is to reliably indicate the particular burners of a multi-burner heating system which have undergone an untimely flame failure.

Another object of this invention is to provide multi-burner control apparatus which reliably and continuously self-monitors its ability to perform its prescribed safeguard functions.

Numerous heating systems in the prior art require combustion chambers having a plurality of burners. It can be readily appreciated that if fewer than all of these burners ignite during a heating period, a dangerous accumulation of unburned fuel vapors might possibly collect within a combustion chamber so that subsequent ignition thereof by one of the properly operating burners or by a hot refractory, for example, results in a destructive blast. In view of the dangers inherent in the operation of fuel burners, it has been customary in the prior art to utilize flame-failure safeguard apparatus to terminate the flow of fuel to a supervised combustion chamber in response to flame failure. In the case of combustion chambers having a plurality of burners wherein a large danger potential is created by a high rate of fuel flow, it is the preferred practice to operate the safeguard apparatus in such a manner that fuel flow to all of the burners is cut off unless all of the burners are operating properly.

Certain multi-burner safeguard controls of the prior art have individual detector-amplifier units associated with each supervised burner so that the amplifier output currents generated in response to detected flame operate a relay whose contact is connected in series with the contacts of similar relays actuated by the other detector-amplifier units. A closed series of relay contacts assures the continuity of the energizing circuit for the burner main fuel valve, thereby providing for an uninterrupted flow of fuel to the combustion chamber. If, however, one or more of the detector-amplifier units fails to operate its associated relay, the series contact chain is broken and the main fuel valve is closed, thereby terminating the flow of fuel to the burners.

In accordance with a preferred embodiment of this invention, safeguard apparatus of improved reliability, which utilizes the chain mode of operation, is attained by electronically mixing the output signals from a plurality of detector-amplifier units individually associated with the burners of a multi-burner assembly, rather than having each amplifier terminate in a relay and placing the relay contacts in series to complete the energizing circuit for the main fuel valve.

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Specifically, an electronic mixing stage is provided for each of the supervised burners. If flame is detected by a photocell which is optically coupled to the burner, sufficient anode potential is applied to the electronic mixer by its associated amplifier so that an input signal applied to the mixer grid circuit will be transmitted to the mixer output. If no flame is detected by the detector-amplifier input, insufficient anode potential will be applied to the electronic mixer to permit transmission of a mixer input signal to the mixer output. In other words, continuous signal transmission throughout the mixer stage is dependent upon the detection of flame by the detector-amplifier unit which supplies the anode potentials for the mixer stage.

The electronic mixers are interconnected in such a manner that the output of one stage is fed into the grid of a second stage, and so on, whereby an open ended chain is formed. An "actuating signal" is applied from the safeguard-apparatus power supply to one end of the chain, and the other end of this chain applies the "actuating signal," which has been transmitted throughout the chain-connected electronic mixers, to a master relay circuit which controls the operation of the fuel solenoid valve for the burners. Each electronic mixer thus provides a link in the chain, which link may be broken if its corresponding detector-amplifier unit fails to detect flame.

The electronic mixers herein described contemplate a conventional cathode-follower circuit. The actuating signal is applied to the grid of a first of these cathode-follower circuits and is transmitted virtually unchanged at the cathode thereof to the grid of the succeeding mixer stage, providing the anode of said contact-follower circuit is supplied with a positive voltage of at least a certain minimum value. This positive voltage is generated by the associated detector-amplifier stage in response to the detection of burner flame.

Another feature of operation of this invention is a novel indicator circuit which includes an individual neon lamp interconnecting each electronic mixer and the safeguard-apparatus power supply in such a manner that flame failure can be attributed to a particular burner by the oper-

ation of one of said lamps. The operation of one of these lamps immediately identifies the particular burner whose flame has failed so that the necessary repairs can be easily made.

Another feature of operation of this invention is the interconnection of a second individual neon lamp between each electronic mixer and the master relay circuit in such a manner that said lamp will illuminate if the supervisory apparatus is incapable of performing its prescribed functions. The illumination of this lamp during the standby intervals between successively heating cycles shows that repairs and maintenance are required before the apparatus can perform its functions.

In order that all of the features of this invention and the mode of operation thereof may be readily understood, a detailed description follows hereinafter with particular reference being made to the drawings, wherein:

Fig. 1 is a functional block diagram showing the chain theory of multi-burner supervision;

Fig. 2 is a functional block diagram of a preferred embodiment of the invention hereof which is characterized by the chain type mode of operation set forth in Fig. 1;

Fig. 3 is an assembly diagram showing the proper physical relationship of Figs. 4 and 5 when viewing the schematic circuit diagram thereof; and

Figs. 4 and 5, when assembled as shown in Fig. 3, provide a complete schematic diagram of the multi-burner control described functionally in Fig. 2.

Referring now to Fig. 1, a plurality of burners numbered B_1 to B_4 are individually monitored by corresponding fire detector units P_1 to P_4. The output of each of these detector units is transmitted to corresponding amplifier units 1 to 4. The power supply furnishes the operating potentials for the fire detectors and the amplifier units, and also the currents which comprise the chain-transmitted actuating signal. It is contemplated that if each of the amplifier units is receiving a flame signal from its associated detector unit, the actuating signal will be transmitted from the power supply in a step-by-step manner throughout all four amplifier units until it reaches the relay circuit. If the actuating signal is transmitted thusly during burner operation, fuel flow to all of the burners is continued. If, however, one or more of burners B_1 to B_4 is extinguished during a heating period, the corresponding amplifier units open the transmission path for the actuating signal so that said signal is no longer transmitted to the relay circuit. If the actuating signal is not transmitted to the relay circuit, a conventional fuel solenoid valve (not shown) is closed, thereby stopping the flow of fuel to all of the burners. It should be understood, that from a generic aspect, the structure herein described may be utilized to promote a variety of obvious control functions in response to flame failure in one or more of a set of supervised burners.

Referring now to Fig. 2, each of the amplifier-mixer units thereof corresponds generally to the amplifier unit blocks of Fig. 1. The input signal to each of these amplifier-mixer units is provided by an associated photoelectric detector unit P. This signal is applied directly to the input of a high-pass amplifier. The output of the high-pass amplifier is transmitted throughout a conventional 60 cycle null filter to the input of a low-pass amplifier. The high-pass amplifier, 60 cycle null filter, and low-pass amplifier together comprise a band pass alternating-current transmission system which readily transmits signal components within the range of approximately 5 to 25 cycles per second and relatively attenuates all other signal components.

As disclosed in the copending applications of P. J. Cade and D. J. MacDougall, Serial Nos. 211,778, which is now abandoned, and 227,166, filed February 19, 1951 and May 19, 1951, respectively, improved flame supervision can be attained by utilizing a device which responds to a certain frequency range of the alternating currents generated by the inherent amplitude fluctuations or flicker found in all types of fire flame. It is disclosed in the aforementioned applications that if the alternating-current components within a range of 5 to 25 cycles are utilized by a fire detection device, the possibility of erroneous supervision is substantially eliminated because of the exclusive generation of frequency components within this range by fire in the usual fire supervised volumes.

The output of the low-pass amplifier is transmitted to an amplifier-rectifier wherein a direct-current potential of substantial amplitude is generated during the supervision of burner flame by the photoelectric cell for the amplifier-mixer unit. This direct-current potential contributes to the energizing currents for the mixer circuit in such a way that transmission of the actuating signal AS, which is generated by the power supply, from the power supply and through each mixer, depends upon the application of a similar positive potential to all of the mixer stages by their respective amplifier-rectifier units.

It can be readily appreciated that if each of burners B_1 to B_4 is in operation, and that if their respective amplifier-rectifier units are applying the requisite direct-current potential to their associated mixer circuits, the actuating signal will be transmitted from the power supply throughout each of the mixer units to the relay circuit. If for any reason one or more of the channels should fail to generate the direct-current potential in response to detected fire flame, insufficient anode potential will be applied to the vacuum tube of the particular mixer circuits to permit the actuating signal to be transmitted therethrough. When this occurs, the relay circuit deenergizes fuel valve FV located in the main supply pipe for burners B_1 to B_4 so that all of the burners are shut down in response to flame failure in one of said burners.

A flame-failure indicator neon lamp N_1 is associated with each of the amplifier-mixer units. Illumination of one of said neon lamps gives a visual indication of the particular burner in which flame has failed. The structure which operates these flame-failure indicator lamps includes conductor DC_1 which applies a direct-current potential from the power supply to the multiple-connected electrodes of each of said lamps. The other electrodes of each of these lamps are connected to the associated mixer circuits so that the direct-current potentials generated in response to detected fire oppose the potential applied by conductor DC_1, thereby preventing operation of said lamps. If flame fails at one of the supervised burners, the direct-current potential at the corresponding mixer circuit is removed so that the potential applied by conductor DC_1 is no longer opposed. This operation results in illumination of the particular neon lamp associated with the burner in which flame has failed.

Conductor DC_2 supplies the operating currents for the amplifier-mixer units.

An individual false-flame indicator lamp N_2 is also associated with each of the amplifier-mixer units. Illumination of one of these lamps indicates that its associated amplifier-mixer unit is operating improperly due to component failure, so that a flame indication is given at the corresponding mixer stage when in fact no flame is detected.

There is shown in Figs. 4 and 5 a preferred schematic embodiment of the invention. The mode of operation thereof corresponds to that of the block diagram of Fig. 2. The particular multi-burner unit shown diagrammatically in Fig. 4 has an upper capped burner and two lower burners B_1 and B_2. The upper burner has been capped merely to show the ease with which one or more amplifier mixer units may be removed or added as the number of supervised burners varies. In a practical installation, it is contemplated that a single amplifier-mixer unit be closely associated physically with each of the burners. The components of each of the amplifier-mixer units are therefore preferably housed within individual housings, and the external connections therebetween are preferably made by cable connections to connectors or plug-in jack means. In view of the fact that the upper burner is capped, economy of components is obtained by providing a dummy plug with a jumper to interconnect cable connectors V and W. This arrangement provides for the necessary interconnection of the amplifier-mixer units which supervise operative burners. Each of the amplifier-mixer units is identical schematically, and therefore only the lowermost unit, which supervises burner B_2, has been shown in detail. The specific description will be confined to this unit.

Photoelectric cell P_2, which is preferably a photoconductive type, is optically coupled to burner B_2. This photoconductive cell is electrically connected to the input of its amplifier-mixer unit by means of conventional cable and connector means.

A solenoid fuel valve FV is located in the main fuel supply pipe for all of the burners. Energization of this fuel valve permits the flow of fuel to the burners, whereas deenergization of the valve cuts off the flow of fuel to the burners. The output potential of the secondary winding of ignition transformer IT is applied to ignition electrodes E_1 and E_2 so that the burners may be ignited in response to a heat demand. The energizing currents for both fuel valve FV and ignition transformer IT are supplied by secondary winding 62 through contact i_2 of interlocking relay I.

In order to simplify the representation of the connections to relays R and I, most of the contacts thereof have been shown in removed relationship with respect to the windings which actuate these contacts. Both normally open and normally closed contacts are identified by lower case letters which correspond to the capital letter designations applied to the actuating relay winding. It will be noted, for example, that relay R actuates normally-closed contact r_1, which is located in the energizing circuit for the primary winding of ignition transformer IT.

Each of the amplifier-mixer units comprises vacuum tubes T_1 to T_4. Generally speaking, T_1 and its associated components are a high-pass amplifier passing frequencies above 5 cycles per second, T_2 and its associated components are a low-pass amplifier passing frequencies below 25 cycles per second, T_3 and its associated components are an amplifier-rectifier, and T_4 and its associated components comprise the novel electronic mixer. Components 12, 13, 14 and 15 comprise a conventional 60 cycle null filter which connects the output of the high-pass amplifier to the input of the low-pass amplifier.

The direct-current potential of power-supply terminal DC_2 is applied to the anodes of tubes T_1, T_2 and T_3 by cable conductor C_3 through cable connector U. The potential of secondary winding 53 is applied to tubes T_1, T_2, T_3 and T_4 by cables C_2 and C_5 through cable connectors X and Y, respectively.

Components 1 and 6 comprise a conventional resistor-capacitor L-type filter section for further filtering the potential of terminal DC_2 before its application to photoconductive cell P_2. Photoconductive cell load resistor 2 applies the relatively smooth direct-current potential appearing at the left terminal of resistor 6 to photoconductive cell P_2. Current fluctuations developed by photoconductive cell P_2 in response to detected flame, or for that matter to any type of incident radiation, appear across load resistor 2. The flame signal variations developed across resistor 2 are applied to serially-connected capacitor 3, resistor 4 and capacitor 5 so that corresponding variations appear at the control grid-cathode space path for tube T_1. The amplified signal output appears across load resistor 8.

The resistance from the upper terminal of capacitor 3 to ground through photoconductive cell P_2 is low compared to the resistance of resistor 4, and when viewed from the right terminal of resistor 7, components 7, 5, 4 and 3 comprise a two section low-pass filter. Capacitor 9 couples the output signal developed across load resistor 8 to the input of the low-pass filter at resistor 7, whereby all signal components developed by photoconductive cell P_2 having a frequency less than approximately 5 cycles per second are fed back through this low-pass filter and consequently do not appear across output load resistor 8. The remaining signal components appearing between ground and the junction of capacitor 9 and grid-return resistor 10, with the exception of a band at approximately 60 cycles, are transmitted substantially unattenuated throughout the conventional split-T filter comprising components 12, 13, 14 and 15.

The unattenuated components transmitted through this filter appear at the right terminal of resistor 13 and are applied to the control grid-cathode space path of tube T_2 through resistor 16. The output for tube T_2 appears across load resistor 20. Components 16, 17, 18 and 19 comprise a high-pass degenerative feed-back path which interconnects the input and output circuits of tube T_2. The values for these components are selected so that all frequency components transmitted to the input of tube T_2 having a frequency greater than approximately 25 cycles per second are substantially attenuated.

The 60 cycle null filter comprising components 12, 13, 14 and 15 is utilized to interconnect the output of tube T_1 to the input of tube T_2, thereby positively attenuating the induced potentials generated in the band-pass amplifier comprising tubes T_1 and T_2 by commercial power distribution systems.

The alternating-current frequency components between 5 and 25 cycles per second developed

across load resistor 20 are coupled by capacitor 23 to shunt resistor combination 24—25, and serially-connected resistor 26 and capacitor 27 connected across said resistor combination. Any potential developed across resistor 26 is applied directly to the control grid-cathode space path of amplifier-rectifier tube T_3. The positive alternations of this potential, measured from the left to the right terminals of resistor 26, cause tube T_3 to draw considerable anode current, whereas the negative alternations tend to cut off anode current flow in tube T_3. Because of this action, capacitor 27 assumes a gradually rising positive direct-current potential above ground and the entire alternating-current potential applied through capacitor 23 appears across resistor 26. Equilibrium is reached across capacitor 27 when that portion of the direct-current potential thereof which appears across resistor 26 plus the peak value of the positive alternations from left to right across resistor 26 exceeds slightly cut-off bias for tube T_3. When equilibrium is reached, the direct-current potential across capacitor 27 is greater than that across resistor 26 by the ratio of the resistance of resistor 26 to the resistance sum of resistor 26 and the parallel combination of resistor 24 and 25. Since the direct-current potential across resistor 26 follows and is nearly equal and opposite to the positive peaks of the alternating-current potential applied through capacitor 23, tube T_3 acts as an amplifier as well as a rectifier. The direct-current potential appearing across capacitor 27 is applied directly to the anode of mixer tube T_4 and constitutes the anode potential for said tube.

Tube T_4 is connected as a conventional cathode follower with the input signal thereto being applied through grid resistor 34, and the output signal thereof being developed across cathode load resistor 32. The actuating signal hereinbefore described in connection with the functional block diagram of Fig. 2 is applied to the right terminal of resistor 34 in a manner which will be described in detail hereinafter. Likewise, resistors 28 and 29, and flame-failure neon lamp N_1 comprise a portion of the flame-failure indicator network described in connection with the block diagram of Fig. 2. Resistor 33 and neon lamp N_2 comprise a portion of the false-flame indicator network described in conjunction with the block diagram of Fig. 2. The detailed operation of flame-failure indicator lamp N_1 and false-flame indicator lamp N_2 will be described in detail hereinafter.

The output signal developed across cathode load resistor 32 is applied to the control grid-cathode space path of the left triode section of tube T_5 by cable conductor C_4 and coupling capacitor 37. When a signal is developed across grid resistor 38, a corresponding out-of-phase signal is developed across load resistor 43 for the left triode section of tube T_5. The signal developed across load resistor 43 is coupled by capacitor 46 to the control grid-cathode space path of the right triode section of tube T_5. If an appreciable potential is developed across resistor 47 and thereby applied to the control grid of the right triode section of tube T_5 through grid current limiting resistor 45, relay R is operated. Secondary winding 62 supplies the negative bias for the right triode section of tube T_5, and resistor 39 supplies the bias for the left triode section of tube T_5.

Secondary winding 60 supplies the alternating plate current for the right triode section of tube T_5. Capacitor 44 shunts the winding of relay R so that the characteristic alternating-current chatter is eliminated. It should be noted that the bias potential applied to the right triode section of tube T_5 by secondary winding 62 is in such a direction as to oppose current flow in the right triode section of tube T_5 due to the potential applied thereto by secondary winding 60. The dotted terminals of both secondary windings 60 and 62 indicate identical polarities.

The anodes of full-wave rectifier tube T_7 are connected to the end terminals of serially-connected windings 60 and 61. The filament of tube T_7 is connected directly to secondary winding 59. Conventional full-wave pulsating direct-current appears at the cathode of tube T_7 and is applied to the input of the resistor-capacitor filter section comprising components 51, 52 and 53. The filtered direct-current output appears at terminal DC_2.

Serially-connected resistors 57 and 58 provide a voltage divider for the secondary potential of winding 61. The junction of resistors 57 and 58 is connected to terminal DC_2 by means of serially-connected resistors 54 and 56. The values for resistors 54, 56, 57 and 58 are so selected that the potential of terminal AS with respect to ground is a direct-current potential with a smaller valued alternating-current potential superimposed thereupon. This composite potential comprises the actuating signal for the chain-connected electronic mixers hereinbefore described.

This actuating signal is applied to cable connector V of the dummy plug by means of cable C_7. The jumper within the plug transmits the actuating signal to cable connector W, at which point the signal is transmitted to cable connector V of the amplifier-mixer unit for burner B_1. This signal is further transmitted to cable connector W for the amplifier-mixer of burner B_1 by a mixer identical to that of tube T_4, providing anode potential is supplied to the mixer tube, whereupon the signal is still further transmitted to cable connector V for the amplifier-mixer unit which supervises burner B_2. This signal is then applied to the control grid of mixer tube T_4 through grid resistor 34. If sufficient potential is applied to the anode of mixer tube T_4 by capacitor 27 in response to the detection of fire flame by photoconductive cell P_2, a corresponding output signal will be developed across resistor 32, which signal is applied to the control grid of the left triode section of tube T_5 by means of cable conductor C_4 and coupling capacitor 37.

The complete transmission of the actuating signal throughout the dummy plug and the mixer circuits for both of the amplifier-mixer units back to the control grid of tube T_5 develops an output signal across load resistor 43 which causes the right triode section of tube T_5 to operate relay R. The closure of the contact r_1 actuated by relay R assures that an operating potential is constantly applied to fuel valve FV whereby burner fuel flow is maintained. If, however, relay R should release its contacts in response to the incomplete transmission of the actuating signal as hereinbefore described, the energizing circuit for fuel valve FV will be opened and consequent closure of the fuel valve will terminate the flow of fuel to burners B_1 and B_2. This operation is provided by the specific actions of the circuitry which includes thermostat TH, manual-starting push button PB and its shunt contact r_3, and parallel-connected contacts r_2 and i_3. Relay I is an interlock relay which prevents the starting up of the burners when one or more of the

amplifier units is incapable of performing its prescribed safeguard functions. The operative details of relay I, push button PB, and thermostat TH, and their interconnecting relay contact network will be described in detail hereinafter.

Gas diode T_6 and resistors **48**, **49** and **55** provide a direct-current potential at terminal DC_1 which is substantially lower than the potential appearing at terminal DC_2. The potential at terminal DC_1 is transmitted by means of cable conductor C_6 to multiple-connected electrodes for each of the lamps corresponding to neon lamp N_1. The remaining electrode for each of these lamps is connected to a voltage divider network comprising resistors **28** and **29**. The plate potential applied to mixer tube T_4 is also applied to serially-connected resistors **28** and **29** so that the portion thereof across resistor **29** appears at one of the electrodes for neon lamp N_1. If flame is detected by photoconductive cell P_2 with the resulting anode potential for tube T_4 appearing across resistors **28** and **29**, neon lamp N_1 will not illuminate because the potential across resistor **29** opposes the potential appearing at terminal DC_1. If, however, photoconductive cell P_2 fails to detect flame so that a direct-current potential no longer appears across resistors **28** and **29**, the potential applied to neon lamp N_1 by terminal DC_1 is sufficiently large to illuminate neon lamp N_1. It is therefore seen that the illumination of neon lamp N_1 is indicative of a flame-failure condition at its associated burner. The breakdown of one of said neon lamps N_1 increases the voltage drop across resistor **49** whereby the supply voltage at DC is too low to permit the remaining lamps N_1 to fire.

The anode of mixer tube T_4 is connected to the control grid of the right triode section of tube T_5 by serially-connected resistor **33**, neon lamp N_2, cable conductor C_1, normally closed contact i_1, and resistor **45**. This particular interconnection provides for the illumination of neon lamp N_2 in response to a false-flame condition in its associated amplifier-mixer unit. In particular, if component failure within the amplifier-mixer unit causes a potential to appear at the anode of mixer tube T_4 when no flame is being supervised by photoconductive cell P_2, this positive potential breaks down neon lamp N_2 causing the right triode section of tube T_5 to actuate relay R by supplying a positive direct-current potential through contact i_1 to resistor **47**. The operation of relay R locks out the safeguard control circuit by opening normally-closed contact r_2, so that fuel valve FV cannot be closed in response to a heat demand until the defective components which created the false-flame condition have been repaired or eliminated.

The detailed sequence of operation of the schematic circuit of Figs. 4 and 5 is as follows. An alternating-current line potential is continuously applied to primary winding **64** of power transformer **63** during both heating and standby periods.

During the standby periods, the direct-current potential at terminal DC_2 is applied to tubes T_1, T_2, T_3 and the right triode section of tube T_5. The alternating-current potential of secondary winding **68** is also applied to the cathode-anode space path of the right triode section of tube T_5 through the winding of relay R. In view of the fact that photoconductive cells P_1 and P_2 are not observing flame, the actuating signal appearing at terminal AS is not transmitted throughout the electronic mixers. As a consequence, the biasing potential applied by secondary winding **62** to the right triode section of tube T_5 is sufficiently great to prevent the operation of relay R. Interlock relay I is also unoperated due to the fact that thermostat TH is open.

The flame-failure indicator lamp N_1 associated with the burner which was first extinguished at the termination of the prior heating period remains continuously illuminated throughout the succeeding standby period. This is because the prior removal of the potential across the corresponding resistor **39** no longer opposes the breakdown potential appearing at terminal DC_1, and all of the other flame-failure neon lamps which are multiple-connected to the operated neon lamp N_1 are locked out in the conventional manner characteristic of parallel-connected negative impedance devices. Therefore only the flame-failure indicator lamp of the burner which was first extinguished at the termination of the prior heating period remains illuminated during a succeeding standby period.

Bimetallic thermostat TH closes its contacts in response to a heat demand at burners B_1 and B_2. Thereafter, push button PB is manually closed providing for the operation of interlock relay I by current flow from secondary winding **62** in a path which comprises thermostat TH, push button PB, normally-closed contact r_2, and the winding of interlock relay I back to secondary **62**. The operation of interlock relay I closes contact i_2 thereby applying the potential of secondary winding **62** to fuel valve FV and the primary winding of ignition transformer IT. Fuel valve FV is therefore opened providing for the flow of fuel to burners B_1 and B_2. In view of the fact that relay R is released at this time, the potential of secondary winding **62** is also applied to the primary of ignition transformer IT through normally-closed contact r_1. The high voltage ignition potential appearing at electrodes E_1 and E_2 ignite the fuel appearing at burners B_1 and B_2 in the conventional manner.

The detection of the burner flames by associated photoconductive cells P_1 and P_2 causes a direct-current potential to be applied to the anodes of their respective mixer tubes in a manner hereinbefore described. With the application of the plate potentials to the mixer tubes, the actuating signal appearing at terminal AS is transmitted throughout the dummy plug, the first amplifier-mixer unit, and the second amplifier-mixer unit back to the control grid of the left triode section of tube T_5. The corresponding signal developed across load resistor **43** applies a potential to the cintrol grid of the right triode section of tube T_5 so that the bias potential of secondary winding **62** is overcome and relay R is energized. The operation of relay R opens normally-closed contact r_1 thereby terminating the ignition potential at burners B_1 and B_2.

After all of the burners have started-up and relay R closes contact r_3 thereby shorting push button PB_1 the push button can be manually released.

If flame should fail during a heating period at burner B_2, for example, the operating potential at the anode of mixer tube T_4 would disappear, and the actuating signal applied to the control grid of mixer tube T_4 would no longer appear across cathode load resistor **32**. Consequently, relay R would release its contacts, thereby opening the energizing circuit for relay I. The opening of contact i_2 would deenergize fuel valve FV and shut down burners B_1 and B_2. Flame-fail-

ure indicator lamp N_1 associated with burner B_2 would also be ignited, because the potential developed across the corresponding resistor 29 would no longer oppose the breakdown potential appearing at terminal DC_1. All other flame-failure indicator lamps would be locked out.

If prior to the starting up of burners B_1 and B_2 in response to heat demand, component failure within one of the amplifier-mixer units should cause the simulation of a flame condition when in fact no flame existed in any of the burners, the potential falsely appearing at the anode of the mixer stage would be transmitted to the control grid of the right triode section of tube T_5 by the corresponding resistor 33, false-flame indicator lamp N_2, cable conductor C_1 and normally closed contact i_1. As a consequence, lamp N_2 would become illuminated thereby giving a visual indication of an improper operating amplifier-mixer unit. The low sustaining potential across the electrodes of lamp N_2 after breakdown would raise the potential of the control grid of the right triode section of tube T_5 a sufficient amount above ground to permit anode current flow in that triode section to operate relay R. The operation of relay R during the standby period would open normally-closed contact r_2 so that subsequent closure of thermostat TH in response to a heat demand, together with manual operation of push button PB, would fail to complete the energizing circuit for interlock relay I. This mode of operation assures that fuel will not be supplied to burners B_1 and B_2 unless the safeguard apparatus is fully capable of performing its prescribed functions.

It is to be understood that the above-described arrangements are illustrative of the applications of the principles of this invention. Numerous other arrangements may be devised by those skilled in the art without departing from the scope of the invention.

What is claimed is:

1. In apparatus for supervising a burner flame, a source of activating signal, a relay to be operated by said activating signal, and a control circuit to apply said activating signal to said relay, said control circuit comprising a cathode follower having an input electrode and an output electrode, means to apply said activating signal to said input electrode, means connecting said output electrode to said relay, potential supply means to render said cathode follower operative, flame detecting means, and means to connect electrically said potential supply means to said cathode follower only when a flame is detected by said detecting means.

2. In apparatus for supervising a burner flame, a source of activating signal, a relay to be operated by said activating signal, and a control circuit to apply said activating signal to said relay, said control circuit comprising a cathode follower having a cathode, a grid and an anode, means to apply said activating signal to said grid, means connecting said cathode to said relay, anode potential supply means to render said cathode follower operative, flame detecting means, and means to connect electrically said anode potential supply means to said anode only when a flame is detected by said detecting means.

3. In apparatus for supervising a plurality of burners, a source of activating signal, a relay to be operated by said activating signal, and a control circuit to apply said activating signal to said relay, said control circuit comprising a plurality of series-connected cathode followers, each having an input electrode and an output electrode, means to apply said activating signal to the input electrode of the first of said cathode followers, means connecting the output electrode of the last of said cathode followers to said relay, potential supply means associated with each cathode follower to render it operative, flame detecting means associated with each potential supply means, and means to connect electrically said potential supply means to its associated cathode follower only when a flame is detected by said detecting means.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,212,352	Plein	Aug. 20, 1940
2,282,551	Yates	May 12, 1942
2,410,524	Richardson et al.	Nov. 5, 1946
2,416,781	Thomson	Mar. 4, 1947
2,431,158	Yates	Nov. 18, 1947
2,567,036	Shannon	Sept. 4, 1951