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BURNER SAFETY CONTROL

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Fig. 1.

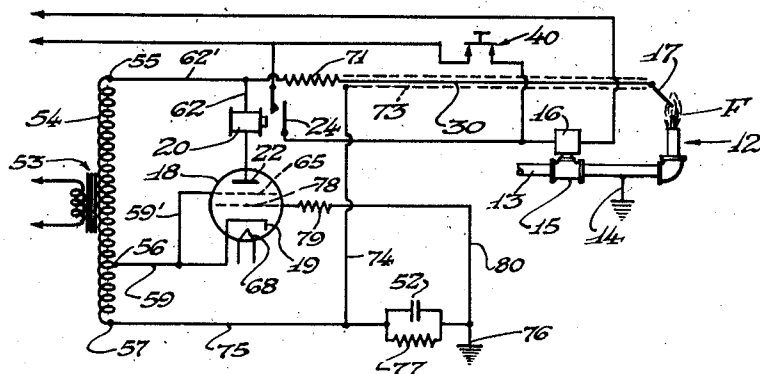
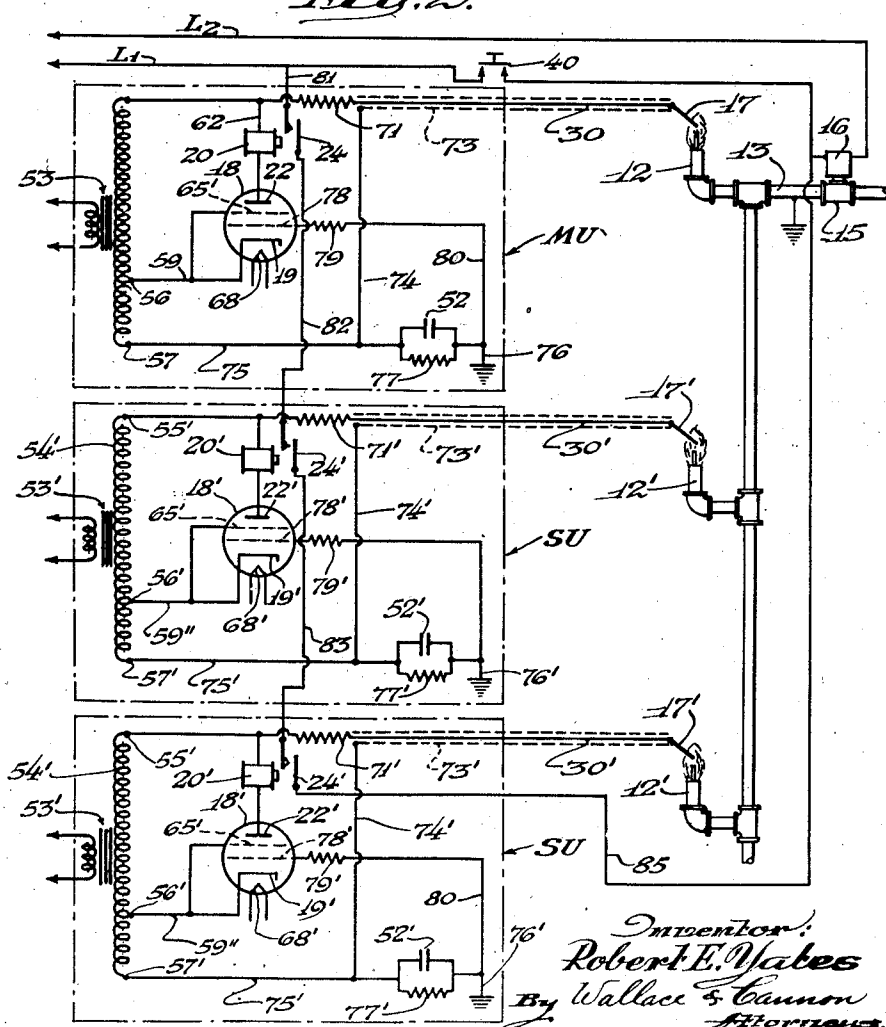


Fig. 2.



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BURNER SAFETY CONTROL

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7 Claims. (Cl. 250—27)

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This application is a division of copending application Serial No. 400,332, filed June 28, 1941.

Heating, baking and drying systems embodying fuel burners or the like are subject to hazards that arise when fuel introduced into a burner is not properly ignited and is thereby enabled to accumulate in an unburned condition in the system wherein the products of combustion from the burner are normally utilized, thereby creating a danger of explosion or other serious damage. It is therefore essential that systems or installations of the aforesaid character be equipped with means for detecting failure of combustion and which will respond automatically in such a contingency to effect a control operation, such as shutting off the supply of fuel to the burner or burners, and thus safeguard the system against risk of explosion or the like.

Numerous types of safety control means or apparatus of the aforesaid character have been heretofore proposed. The earlier forms of such apparatus entailed the use of heat-sensitive devices such as thermostats, thermocouples, pressure diaphragms and the like which were indirectly responsive to the presence or absence of a flame in a burner for effecting whatever control operations were necessary with respect to the burner. Such devices were generally unreliable because an appreciable time lag was entailed in the operation thereof and such devices were readily affected by disturbances such as external air drafts which had no direct relation to combustion conditions in the burner. Later forms of flame detectors have operated in dependence upon the flow of electrical current across a gap between a pair of spaced electrodes that are arranged to be bridged by the flame of the burner. Usually one of these electrodes constitutes what is known in the art as a flame rod which is disposed in the flame zone of the burner so as to be contacted by a flame when one is present, while the other electrode may consist of another flame rod similarly situated or it may be afforded by a portion of the burner structure itself. Flame detectors of this character may be roughly divided into several classes.

One class of such apparatus entails an arrangement in which the value of an ohmic resistance of the electrical path between the electrodes is the determining factor in the operation of the apparatus, the magnitude of this resistance being governed by the presence or absence of flame in the burner. This class in turn may be said to comprise at least two varieties. In one of these the electrical current flow through the flame path

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is produced by impressing a relatively high voltage across the flame-sensing electrodes, this voltage being sufficient to set up a current having a great enough magnitude (provided a flame is present) to operate a relay or the like. In the other form of this apparatus an alternating-current voltage is impressed upon the flame-sensing circuit and an electron tube means is arranged to be governed not only according to the magnitude of the current flow through the flame gap, but also in response to the phase relation of this current with respect to the impressed voltage. An example of the last-mentioned apparatus is disclosed in my Patent No. 2,282,551, patented May 12, 1942, and one of its outstanding advantages is that it operates to detect not only flame failure but also an unsafe condition which may arise when the flame gap is accidentally short-circuited.

Another of the classes of flame detectors to which reference has been made hereinabove entails an arrangement in which the conduction of electrical current through the flame is made to depend not so much upon the conductivity of the flame itself as upon the electron-emitting properties of an electrode which is arranged to be heated by the flame. Such flame detectors tend to be unduly sensitive and moreover are unsatisfactory when used on alternating-current because of the fact that the flame itself has a current-rectifying effect which tends to block the unidirectional flow of current set up by thermionic emission, unless the electrodes are so arranged that the emitted electrons travel from the hot to the cool electrode substantially in the direction of flame propagation (that is, away from the burner nozzle). It is disadvantageous to arrange the electrodes in this manner, however, because the cool electrode must then be placed outside of, but very close to, the edge of the flame and any fluctuations of the flame due to cross-drafts or the like may produce corresponding fluctuations in the flow of electron current, with detrimental effects upon the accuracy of operation.

Still another class of flame detecting safety devices is that wherein the arrangement makes use of the substantially unilateral conductivity of a flame without relying upon any thermionic emission characteristics of an electrode. Because of the greater ease with which a current of electrons or negative ions may flow in the direction of flame propagation than contrary thereto, a substantially unidirectional flow of negative ions or electron current takes place between the spaced elec-

trodes in a direction away from the burner nozzle when an alternating-current voltage is impressed across these electrodes. This unidirectional or rectified current is utilized to charge a dielectric body such as a condenser to thereby control the potential applied to the control element or grid of an electron tube and thus regulate the amount of current flow in an output circuit of the tube. If the flame is extinguished or becomes too low, the rectified current flow ceases and the condenser loses its charge, the effect of this being to so condition the electron tube circuit that a control operation is effected or a warning signal given.

The present invention falls in the last mentioned class, but it affords several features which are not realized in prior devices of this character, and particularly it takes into consideration the possibility that the flame-sensing means itself may become defective in several respects and thereby cease to afford protection for the burner system. For example, a flame-sensing rod or electrode may become softened due to the heat of the flame and may therefore so bend that it engages a part of the burner. This is dangerous because the flame is short-circuited and is therefore no longer included in the input circuit of the electron tube, so that the apparatus is adapted to function safely upon the occurrence of such a contingency. Then again, instead of there being a direct electrical contact of the flame rod with the burner there may be an accumulation of hygroscopic, carbonaceous or other electrically conductive substance extending between the flame rod and the burner which has a leakage or shunting effect that may simulate a flame even when there is no combustion of the fuel in the burner. It is likewise possible that sufficient leakage may take place through the insulation surrounding the conductors in the flame-sensing circuit to produce a condition simulating the presence of flame in the burner. Prior safety control devices operating on the flame rectification principle were unable to prevent misoperation of the system under at least some of the circumstances enumerated above and therefore an important object of the present invention is to improve such safety apparatus in these respects.

Heretofore it has been proposed to afford means for checking leakage effects such as have just been described in a number of ways, as by providing one of the flame-sensing electrodes with a sleeve that is intended to intercept any leakage current passing between the electrodes by a path other than through the burner flame, and upon the occurrence of excess leakage from an electrode to such a sleeve the apparatus is intended to react as though there had been a flame failure. Such an arrangement is unsatisfactory because obviously the sleeve cannot extend into the flame zone since it would then prevent the proper operation of the device, and hence it is ineffective to detect the leakage paths in this region.

Other prior devices of the character which function in dependence upon the ohmic resistance of the flame path have dispensed with the special sleeve on the flame-sensing electrode, and it has been intended in certain of these devices that they are to react safely whenever there is any substantial leakage from an electrode other than the normal flow of current through the flame, whether this exists by reason of short-circuiting, insulation failure or carbonization of the electrode in the region of the flame itself. In

these prior devices an all-around leakage check of the flame-sensing circuit is made as a condition precedent to operation of the system. However, once the operation of the burners has been initiated, the safety apparatus thereafter functions to detect only flame failure or the existence of a low-resistance shunt path between the flame electrodes, and it will not operate safely upon flame failure if a leakage path having a resistance comparable with that of a normal flame path is established between the flame electrodes in the region of the flame while the burner is in operation. Usually in such burner systems a safe reaction of the control apparatus in response to the detection of current leakage conditions in a burner does not occur until the system has been recycled, that is, disabled due to the operation of some other means such as a room thermostat and then started up again, and if such recycling does not occur soon enough, a risk of explosion is created.

Hence, a further object of my invention is to enable the control apparatus to recognize all of the unsafe conditions enumerated hereinabove, and particularly to ascertain whether the electrical path existing between the flame-sensing electrodes while the burner is in operation is afforded by the flame itself or whether the electrodes have become electrically connected in some other manner, especially by a bilaterally conductive shunt or leakage path having an ohmic resistance of a value comparable with that of a normal flame path.

A still further object is to adapt the safety control apparatus for use in multiple burner systems in a novel manner without unnecessary duplication of parts and at the same time to afford the features and advantages described hereinabove.

A further object of the invention is to afford a control apparatus wherein electron tubes embodied in the apparatus are checked as to conductivity and operativeness prior to the initiation of the operation of the fuel burning system and during the entire time that the system is in operation, and an object related to the foregoing is to render an electron tube conductive in response to the sensing of a flame in a burner and non-conductive when there is a failure of combustion or upon establishment of a short circuit or leakage path through the flame gap, and in this way any internal failure of the tube which causes it to become permanently nonconductive immediately produces the same reaction of the control apparatus as though any of the aforesaid unsafe conditions had been detected. An ancillary object is to so arrange the dielectric body or condenser that it is adapted to be unidirectionally charged during forward half-cycles of the alternating current, when a flame is present in the burner, and discharged upon flame failure or whenever the normal flame path is shunted.

Other and further objects of the present invention will be apparent from the following description and claims and will be understood by reference to the accompanying drawings which, by way of illustration, show preferred embodiments and the principle thereof and what I now consider to be the best mode in which I have contemplated applying that principle. Other embodiments of the invention embodying the same or equivalent principle may be used and structural changes may be made as desired by those skilled in the art without departing from the

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present invention and the purview of the appended claims.

In the drawings,

Fig. 1 is a diagrammatic view of the basic form of the invention; and

Fig. 2 is a diagrammatic view similar to Fig. 1 but illustrating one manner in which the invention may be adapted for use in a multiple burner system.

Referring first to Fig. 1, wherein the basic construction is shown, it will be observed that the apparatus is adapted to control the operation of a burner generally designated 12 which is supplied with fuel through a pipe 13 that is grounded as indicated at 14. A self-closing fuel valve 15 having an operating solenoid 16 is embodied in the fuel supply pipe 13 to prevent the supply of fuel to the burner 12 when the solenoid 16 is in a deenergized condition. The burner 12 is equipped with a flame-sensing rod or electrode 17 which is insulatedly mounted in such a manner as to extend into the flame F of the burner when such a flame is present, the electrode 17 being maintained in predetermined spaced relation with the tip or nozzle of the burner 12. The electrode 17 is preferably made of a heat-resisting, electrically conductive material having substantially no thermionic emissivity. In the present instance the burner 12, being grounded, constitutes the other electrode; however, it will be understood that a second rod such as 17 positioned closer to the nozzle of the burner than the first rod 17 may be employed equally well for this purpose.

The control apparatus constituting the preferred form of the present invention includes an electron tube 18 which is diagrammatically represented in Fig. 1 as being of the tetrode type, having a shield grid 65 connected directly to the cathode 19. Other types of tubes such as triodes may be utilized in place of the tube 18, but for the purposes of the present invention a tetrode has been found to be the most satisfactory. I prefer to employ a gas-filled electron tube 18 in order to afford a trigger action, but here again it is to be understood that I do not limit myself to such a tube since a vacuum tube may be utilized in lieu thereof if desired.

Alternating current is supplied to the apparatus by a suitable source such as transformer 53 having a secondary winding 54 provided with three taps 55, 56 and 57, the tap 56 being electrically intermediate the taps 55 and 57. The cathode 19 of the tube 18 is connected by a conductor 59 to the tap 56, and a branch lead 59' from the conductor 59 connects the shield grid 65 electrically to the cathode 19. The filament 68 is supplied with current from a suitable source in accordance with usual practice. The anode 22 of the tube 18 is connected through the winding of a relay 20 to conductors 62 and 62' leading in series to the tap 55. The relay 20 has a contact 24 which is normally open when the relay is deenergized and which closes when the relay is energized to complete a circuit for energizing the fuel valve solenoid 16.

The burner 12 is equipped with a flame-sensing electrode 17 which is connected by a conductor 30 to a resistor 71 and thence through this resistor to the conductor 62' leading to the transformer tap 55. A protective sheath 73 surrounding and electrically insulated from the conductor 30 is electrically connected by conductor 74 to a conductor 75 leading to the transformer tap 57. A condenser 52 is connected on one side to the conductor 75 and on its other side to ground as

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indicated at 76. A resistor 77 is connected in parallel with the condenser 72 so as to afford a leakage path for the condenser. The tube 18 has a control grid 78 which is connected through a protective resistor 79 and a conductor 80 to ground as indicated at 76.

The voltage induced in that section of the transformer secondary 54 between the taps 56 and 57 affords a negative bias for the control grid 78 of the tube 18 during the forward half-cycles of the alternating current when the anode 22 is at a positive potential with respect to the cathode 19, and this negative bias tends to render the tube 18 non-conductive.

It has been explained hereinabove that a flame as F in a fuel burner as 12 has the property of rectifying alternating current; that is, during those half-cycles in which the burner 12 is negative with respect to the electrode 17, electrons or negative ions may flow from the burner 12 to the electrode 17 in the direction of flame propagation, provided a flame as F is present, thereby producing current flow from the electrode 17 to the burner 12. However, during the intervening half-cycles substantially no current flow can take place through the flame F between the electrode 17 and the burner 12.

As the apparatus is arranged in Fig. 1 the tube 18, insofar as the bias between anode and cathode is concerned, tends to be conductive in those half-cycles of the alternating current in which the anode 22 is positive with respect to the cathode 19, or in other words, during the forward half-cycles. It will be understood, however, that the normal negative bias on the control grid 78 overcomes this tendency of the tube to be conductive in such forward half-cycles of the alternating current unless this normal negative bias of the control grid is reduced in response to the presence of a flame F, as will be hereinafter described. During such forward half-cycles of the alternating current the electrode 17 is positive with respect to the burner 12, and therefore electrons or negative ions may flow from the burner 12 to the electrode 17 in the direction of flame propagation, provided a flame is present. However, during the intervening or inverse half-cycles of the alternating current the electrode 17 is negative with respect to the burner 12 and therefore the flame F is effective to block the flow of electron current between the burner 12 and the electrode 17. Thus, when a flame F is present in the burner 12, the current flows through the flame-sensing circuit during forward half-cycles of the alternating current, this circuit extending from the transformer tap 55 through the resistor 71, the conductor 30, the electrode 17, the flame F, the burner 12, the condenser 52 and the resistor 77 in parallel, and the conductor 75 to the transformer tap 57. Due to the rectifying effect of the flame F, this current is of a non-bilateral character so that the condenser 52 assumes a substantially unidirectional charge to thereby produce a direct-current voltage drop between points 57 and 76 which tends to counteract the negative bias on the control grid 78. So long as the flow of rectified current continues in the flame-sensing circuit this voltage drop will be of such a direction and magnitude that the potential of the control grid 78 with respect to the cathode 19 is more positive than is the firing voltage of the tube 18. Under these circumstances the tube 18 is rendered conductive during the forward half-cycles of the alternating current, and a pulsating current is passed through the winding of

the relay 20 to maintain this relay energized, and the relay contact 24, therefore, remains closed and maintains the fuel valve solenoid 16 energized to thereby enable fuel to be supplied to the burner 12.

In the event that the flame F in the burner 12 is accidentally extinguished, the flow of rectified current through the aforesaid flame-sensing circuit ceases and the charge on the condenser 52 leaks off through the resistor 77. Since there is no longer any substantial voltage difference between the points 57 and 76 to counteract the negative bias applied to the control grid 78, the tube 18 ceases to conduct current and the relay 20 deenergizes to open its contact 24. This results in deenergization of the solenoid 16 and consequent closure of the fuel valve 15 to prevent emission of unburned fuel from the burner 12.

If the flame electrode 17 accidentally becomes grounded as by engaging the burner 12, alternating current is passed through the condenser 52, and under these circumstances substantially all of the voltage between the transformer taps 55 and 57 is absorbed in the resistor 77, the circuit being so designed that on alternating current the condenser 52 acts as a low-impedance shunt around the resistor 77. Because of the decreased voltage drop between the points 57 and 76, the potential of the control grid 78 relative to the cathode 19 becomes more negative than the firing voltage of the tube during the forward half-cycles of the alternating current, thereby rendering the tube 18 non-conductive.

Similarly, if there is a bilateral leakage path existing between the electrode 17 and ground, so that alternating current is passed through the flame-sensing circuit, the condenser 52 serves to shunt the resistor 77, causing the tube 18 to become non-conductive. Failure of the insulation between the conductor 30 and the sheath 73 producing excessive leakage currents has a shunting effect upon the condenser 52 which likewise renders the condenser ineffective to maintain the tube 18 in a conductive state, and the same is true if the sheath 73 becomes grounded.

For purposes of initiating operation of the burner 12 after it has been disabled by the safety apparatus, a normally open switch 40 may be connected in parallel with the relay contact 24 in the fuel valve energizing circuit. This switch is momentarily closed by the operator to energize the solenoid 16 independently of the relay 20 to enable fuel to be supplied to the burner 12. The fuel is ignited by a suitable ignition means (not shown) which is temporarily rendered operative for the purpose of starting the burner in operation, such ignition means preferably being under the control of the starting switch 40. When the operator ascertains that the fuel has been properly ignited, he releases the starting switch 40 and thereafter the energizing circuit for the fuel control valve solenoid 16 is maintained closed through the contact 24 of the relay 20 (the tube 18 having been rendered conductive as hereinbefore described upon the establishment of a flame F in the burner 12) unless and until a hazardous condition again arises requiring a shut down of the system.

It has been stated hereinabove that the present invention may be readily adapted for use in multiple burner systems, and one such arrangement for achieving this object is diagrammatically illustrated in Fig. 2. Thus, there is provided a master control unit designated MU which is substantially identical with the device shown in Fig. 1,

and which is operatively associated with one of the fuel burners 12 included in a bank of burners that are supplied with fuel by a single pipe 13 having the necessary branch connections to the various burners. Corresponding parts of the structure shown in Figs. 1 and 2 are designated by like reference characters and it will be understood that the operation of the master control unit MU is substantially the same as that of the apparatus shown in Fig. 1.

In addition to the master control unit MU there are provided a plurality of secondary control units designated SU which are respectively associated with the other burners 12' of the system in much the same manner as the master unit MU is associated with the burner 12. Thus, each burner 12' has an electrode 17' which is connected by a shielded conductor 30' to the control grid 78' of the electron tube 18' in the respective secondary unit SU. The shielded conductors 30 and 30' may be passed through individual grounded conduits or it may be preferred to run these conductors through a common conduit for at least a portion of the respective lengths. The secondary units are substantially identical in construction with the master unit MU except that the relays as 20', have their relay contacts connected in series, as will be presently described, to jointly govern the operation of the solenoid 16 of the normally closed fuel valve 15 which controls the fuel supply to all of the burners 12, and hence corresponding parts of the master and secondary control units bear similar reference characters which differ only in the prime suffixes. The anodes 22' of the tubes 18' in the several secondary units SU are connected through the coils of their respective relays 20' to the taps 55' of their respective transformer secondaries 54' in the same manner as in the master control unit MU. In like manner the cathode 19 of the tube 18 and the cathodes 19' of the tubes 18' are all electrically connected by wires 59 and 59', respectively, the taps 56 of their respective transformer secondaries 54 and 54'. Hence, the electron tubes 18 and 18' in the various control units are connected and operate in the same manner as in the embodiment of the invention shown in Fig. 1, and anode current of these tubes passes through the windings of their respective relays 20 and 20' to close the contacts 24 and 24' thereof in response to the presence of a flame at their respective burners 12 and 12'. A wire 81 connects a line wire 11 to the stationary contact of the relay 20, a wire 82 connects the relay contact 24 to the stationary contact of the relay 20' of the first secondary unit SU, a wire 83 connects the relay contact 24 of this secondary unit SU to the stationary contact of the relay 20' of the next unit SU, and so on until the last of the unit SU has been thus connected, and the contact 24 of the last unit SU is connected by a wire 85 to one terminal of the solenoid 16; and since the other terminal of the solenoid 16 is connected to the other line wire L2, the solenoid 16 is controlled by a series circuit which may be broken by opening of any one of the relay contacts 24 or 24'.

It will be recalled that the tubes 18 are normally biased so as to be nonconductive, and that when a flame as F is present in a burner as 12 the associated tube as 18 is rendered conductive. Similarly, the tubes 18' are normally biased so as to be nonconductive and when the flames are present in all of the other burners 12' the corresponding tubes 18' are all conductive, and hence the relays 20 and 20' are energized when a flame

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is present at all of the burners. However, if a flame in any one of the burners becomes extinguished, or too low, the tube 18 or 18' associated with such burner is rendered non-conductive so that current flow stops place in the associated relay coil, which relay thereupon deenergizes and opens its contact 24. The fuel supply pipe 13 has a valve 15 controlled by the solenoid 16 which receives its energizing current through the relay contacts 24 and 24' of all of the relays 20 and 20' in series, and when a relay 20 or 20' deenergizes to open the contact 24 or 24' thereof the solenoid 16 deenergizes and enables the fuel valve 15 to close and thereby interrupt the supply of fuel to all of the burners in the system.

The other safety features described hereinabove in connection with the circuit of Fig. 1 are also afforded in the case of each and every control unit in the multiple system as shown in Fig. 2. Thus, if there is a shunting of the flame gap in any particular burner due to grounding out of the flame-sensing electrode or the building up of a non-rectifying resistance path across the flame gap as a result of carbonization and the like, the electron tube in the control unit associated with that burner is rendered nonconductive so as to deenergize its relay and thereby break the circuit to the fuel valve solenoid and shut off the supply of fuel. The same is true if there is an insulation failure which causes excessive leakage in the cable including a conductor 30 or 30' leading to the flame electrode of a particular burner. Hence, a dependable safety control apparatus for a multiple burner system is afforded.

From the foregoing description it will be apparent that the invention provides a safety control apparatus of novel and economical construction and which is more reliable in operation than the control devices heretofore employed to govern fuel burner systems and the like. Thus, the present apparatus acts to protect the burner system against hazards which arise not only when the fuel admitted to a burner or burners is improperly ignited resulting in a failure of combustion, but also when the safety control apparatus itself becomes defective in any of a number of different ways. For example, where the apparatus is adapted to respond to the flow of electrical current through a gap between spaced electrodes positioned in the region of a flame in a burner, as is done in the present instance, there is always the possibility that the aforesaid electrical path through the flame may be accidentally shunted due to a flame-sensing electrode coming into electrical contact with the other electrically conductive substances such as carbon accumulating on a flame-sensing electrode or on the surface of the insulators supporting such electrode, and in some instances the ohmic resistance of this shunt path may be of a value comparable with that of a normal flame path so that the gap between the electrodes has substantially the same conductivity (except that it is of bilateral rather than unilateral character) in the absence of a flame as would normally be the case when a flame is present. The present invention is adapted to guard against dangers attending such improper conditions in the burner and is particularly useful and advantageous in that all of these safety features are afforded in the same apparatus without unduly complicating the construction thereof.

In the present invention the unilateral electrical characteristics of flames are utilized to control the operation of electron tubes for the purpose of producing a safe response upon the oc-

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currence of any of the undesirable contingencies mentioned above, and the arrangement is such that an electron tube is rendered conductive when a flame is present in the burner and non-conductive if the flame is extinguished or the electrical path through the flame is shunted so as to nullify the current-rectifying effect of the flame. This may be conveniently accomplished, as taught in the present disclosure, by utilizing the current-rectifying properties of a flame to impart a unidirectional charge to a condenser or other dielectric medium, and applying a bias potential to the control grid of the electron tube in response to the establishment of such unidirectional charge on the condenser. Preferably the apparatus is operated on alternating current and so long as the tube is maintained in a continuously conductive condition fuel may be admitted to the burner. However, if there is a failure of combustion or the flame path becomes shunted, the condenser loses its unidirectional charge and the electron tube is then rendered nonconductive. Means under control of the electron tube thereupon operate to interrupt the supply of fuel to the burner so that unburned fuel cannot be emitted by the burner. It will be understood, of course, that any other or additional control operations with respect to the fuel burner may be performed by the apparatus when an unsafe condition exists, such as operating an alarm or automatically operating an ignition means to reignite the fuel.

The present burner control is so arranged that the electron tube is rendered conductive when a flame is present in the burner and nonconductive whenever there is a flame failure or shunting of the flame gap due to a short circuit or leakage between the flame electrodes, and this feature is important because it enables the apparatus to react safely whenever a tube assumes a permanently nonconductive state as a result of internal failure. Such an apparatus has been found to be particularly applicable to single burner installations. Another feature of the present invention is that it may be readily adapted to use in connection with multiple burner systems as well as with single burners. In multiple burner operation unnecessary duplication of fuel valves is avoided by providing a single master control unit to control a common fuel supply means, and a plurality of secondary control units each operatively associated with a respective burner, each of said control units responding to conditions in its burner to govern the common fuel supply means.

Still another advantage of the present invention is that if the insulation surrounding the conductors in a flame-sensing circuit becomes faulty so as to enable excessive leakage of current to take place through the insulation, the apparatus is able to detect such conditions and respond in a safe manner. This is particularly important where the apparatus is to be utilized in chemical plants or the like where the insulation is subject to damage from corrosion or other causes.

While I have illustrated and described selected embodiments of my invention, it is to be understood that these are capable of variation and modification and I therefore do not wish to be limited to the precise details set forth but desire to avail myself of such changes and alterations as fall within the purview of the following claims.

I claim:

1. In a flame detecting device for detecting the presence of a flame in a fuel burner or the like, an electron tube having a control element nor-

mally biased to render said tube nonconductive, a condenser effective when charged unidirectionally in a given sense to nullify the bias on said control element and thereby render said tube conductive, and means providing a circuit extending from an alternating current source and including a pair of electrodes insulated from each other and adapted to be positioned in the path of a flame of substantially unilateral conductivity and through said condenser whereby said condenser tends to become charged unidirectionally for rendering said tube conductive when a flame is present, said circuit also embodying a first resistor connected in parallel with said condenser for causing said condenser to lose its unidirectional charge and thereby become ineffective to prevent said tube from assuming a nonconductive state when said circuit is interrupted due to flame failure, and a second resistor connected in series with said condenser and effective when said flame path is short-circuited to so limit the magnitude of the charge on said condenser as to render said tube nonconductive.

2. In a flame detector operating in dependence upon the property of a flame to conduct electrical current between two spaced electrodes more readily when the first of said electrodes is positive with respect to the second electrode than when the relative polarities of said electrodes are reversed, the combination of an alternating current transformer having three taps, the potential of the second tap being intermediate the potentials of the first and third taps; an electron tube having an anode, a cathode and a control grid; means electrically connecting said anode to said first tap, means electrically connecting said cathode to said second tap, a first resistor, a condenser; a pair of electrodes insulated from each other and adapted to be located in the path of a flame with one of said electrodes spaced from the other in the direction of propagation of the flame, circuit means electrically connecting said condenser in circuit from said third transformer tap to said other electrode, means electrically connecting said one electrode through said first resistor to said first transformer tap, said first electrode being intermediate said first tap and said second electrode, a second resistor connected in parallel with said condenser, and means electrically connecting said control grid to said circuit means between said condenser and said other electrode, whereby said tube is rendered conductive only in response to the establishment of a substantially unidirectional charge on said condenser whenever said electrodes are electrically interconnected solely through the unidirectionally conductive medium of a flame, and said tube becomes nonconductive upon flame failure as well as when a bilateral electrical connection of any kind or any resistive value exists between said electrodes.

3. In a flame detector operating in dependence upon the property of a flame to conduct electrical current between two spaced electrodes more readily when the first of said electrodes is positive with respect to the second electrode than when the relative polarities of said electrodes are reversed, the combination of an alternating current transformer having a secondary provided with three taps, the potential of the second tap being intermediate the potentials of the first and third taps; an electron tube having an anode, a cathode and a control grid; means electrically connecting said anode to said first

tap, means electrically connecting said cathode to said second tap, means including a first resistor connecting said first electrode to said first tap, a condenser through which said second electrode is connected to said third tap, a second resistor connected in parallel with said condenser, and a third resistor connecting said control grid to said second electrode, whereby said tube is rendered conductive only in response to the establishment of a substantially unidirectional charge on said condenser whenever said electrodes are electrically interconnected solely through the unidirectionally conductive medium of a flame, said tube becoming nonconductive upon flame failure as well as when a bilateral electrical connection of any kind or any resistive value exists between said electrodes.

4. In a flame responsive device, an electronic discharge device having an anode, a cathode and a control grid, a pair of spaced electrodes insulated from each other and adapted to be positioned in the path of a flame with a particular one of said electrodes displaced from the other of said electrodes in the direction of propagation of the flame, a source of alternating electric current having a first, a second and third tap, a control circuit connected between said first tap of said source and said anode and from said second tap to said cathode, circuit means connecting said third tap to said cathode and said control grid to normally render said discharge device nonconductive during those cycles of the alternating current when said anode is positive with respect to said cathode, said circuit means including a capacitance and a resistance arranged in parallel and disposed in and forming a part of said circuit means, a flame sensing circuit including means affording an alternating current path from said other electrode to the terminal of said capacitance that is electrically adjacent to said grid, and said flame sensing circuit also means affording an alternating current path from said particular electrode to said third tap of said source, and said flame sensing circuit further including resistance means operable in the event of grounding of said particular electrode or in the event of bilateral conductivity of said flame sensing circuit to limit the instantaneous charge impressed on said capacitance to an amount insufficient to render said electron discharge device conductive.

5. In a flame responsive device, an electronic discharge device having an anode, a cathode and a control grid, a pair of spaced electrodes insulated from each other and adapted to be positioned in the path of a flame with a particular one of said electrodes displaced from the other of said electrodes in the direction of propagation of the flame, a source of alternating electric current having first and second taps, a control circuit including means connecting said first tap of said source to said anode, means including a cathode connection and a control grid connection associating said cathode and grid with said second tap to normally render said discharge device nonconductive during those cycles of the alternating current when said anode is positive with respect to said cathode, circuit means affording an alternating current path from said particular electrode to said one tap of said source, means affording an alternating current path from said other electrode to said control grid connection at a particular point therein, said control grid connection intermediate said particular point and said second tap including a

capacitance and a resistor in parallel, whereby bridging of said electrodes by a flame propagated in a direction extending from said other electrode to said particular electrode charges said condenser in such a sense that positive bias is applied to said control electrode to nullify the normal negative bias thereon and render said discharge device conductive, and a limiting resistor included in said circuit means and operable when said particular electrode is grounded to so limit the instantaneous charge on said capacitance as to render said capacitance ineffective to nullify the normally negative bias on said grid.

6. In a flame responsive device, a pair of electrodes insulated from each other and adapted to be positioned in a flame with one of said electrodes spaced from the other of said electrodes in the direction of propagation of the flame, an electron discharge device having an anode, a cathode and a control grid, a source of alternating electrical energy having first and second taps, means connecting said anode to said first tap of said source, circuit means including a cathode connection and a control grid connection associating said cathode and said control grid with said second tap of said source to normally render said discharge device nonconductive during those cycles of the alternating current when said anode is positive with respect to said cathode, a conductor including a protective resistor connecting said one electrode to said first tap of said source, a sheath protecting at least a portion of said conductor and arranged in insulated relation to said conductor, said control grid connection including a capacitance and a resistance in parallel in said connection, means connecting said sheath to said control grid connection between said capacitance and said second tap of said source, and means affording an alternating current path between the other side of said condenser and said other electrode.

7. In a device for detecting the presence of a flame in a fuel burner or the like, an electron tube having an anode, a cathode and a control grid, an alternating current source connected to said anode and cathode to afford an anode-cathode circuit, means including a condenser and a resistance in parallel and connected between said grid

and said source to normally bias said control grid negative with respect to said cathode during that portion of each alternating cycle when said anode is positive with respect to the cathode to thereby normally block said tube and render the same non-conductive, said condenser being effective when charged unidirectionally in a given sense and in a predetermined amount to nullify the normal blocking action of said grid and thereby render said tube conductive, and means providing a flame-sensing circuit including said alternating current source and extending through a path in said flame of substantially unilateral conductivity and through said condenser in such a sense in respect to the anode-cathode circuit of said tube and with respect to the direction of propagation of said flame that said condenser tends to become charged unidirectionally for rendering said tube conductive when a flame is present, and means in said flame-sensing circuit operable to limit the magnitude of the instantaneous alternating current charge impressed on said condenser and said control grid in each cycle of the alternating current to a value insufficient to render said tube conductive whereby said control grid is ineffective to render said tube conductive when said flame-sensing circuit is bilaterally conductive.

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