Nov. 5, 1946. D. E. RICHARDSON ET AL 2,410,524

BURNER SAFETY CONTROL

Filed June 28, 1941 6 Sheets-Sheet 1

Fig. 1.

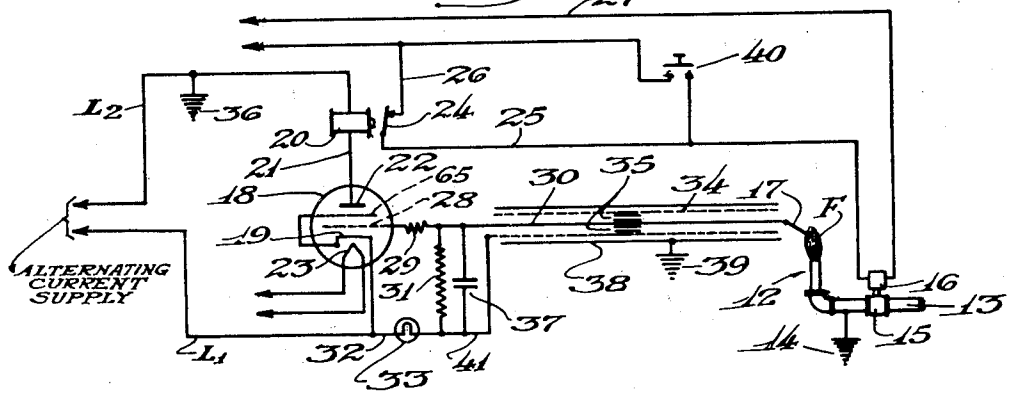
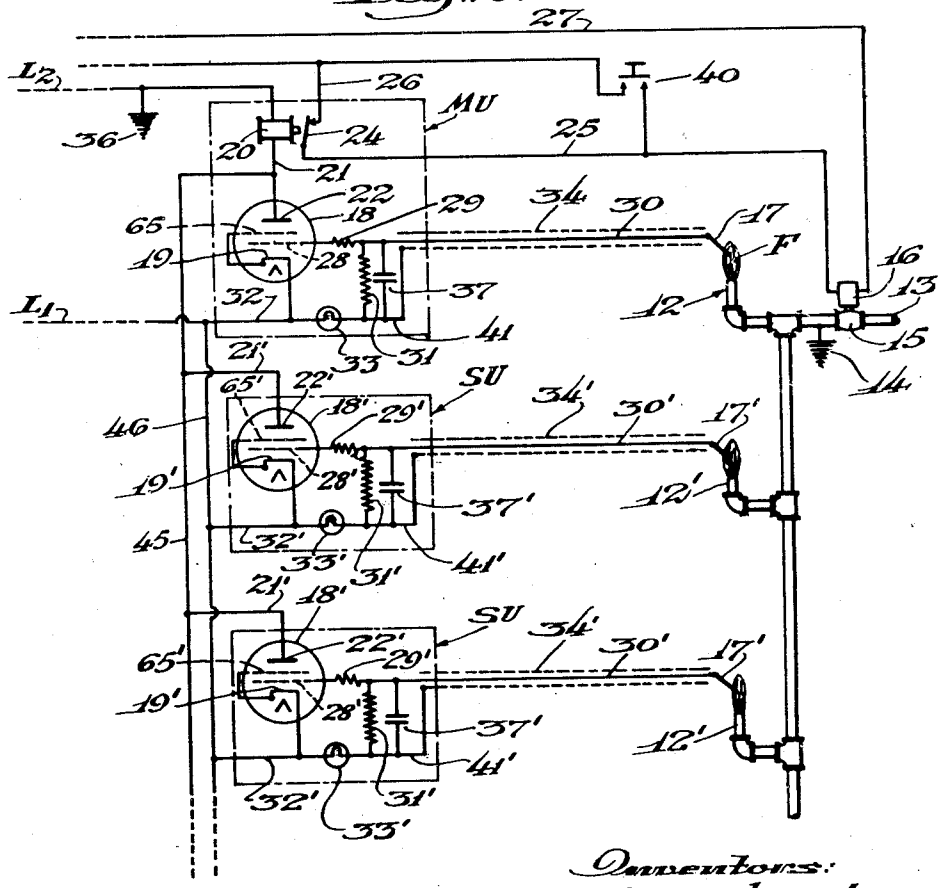


Fig. 2.



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BURNER SAFETY CONTROL

Filed June 28, 1941 6 Sheets-Sheet 2

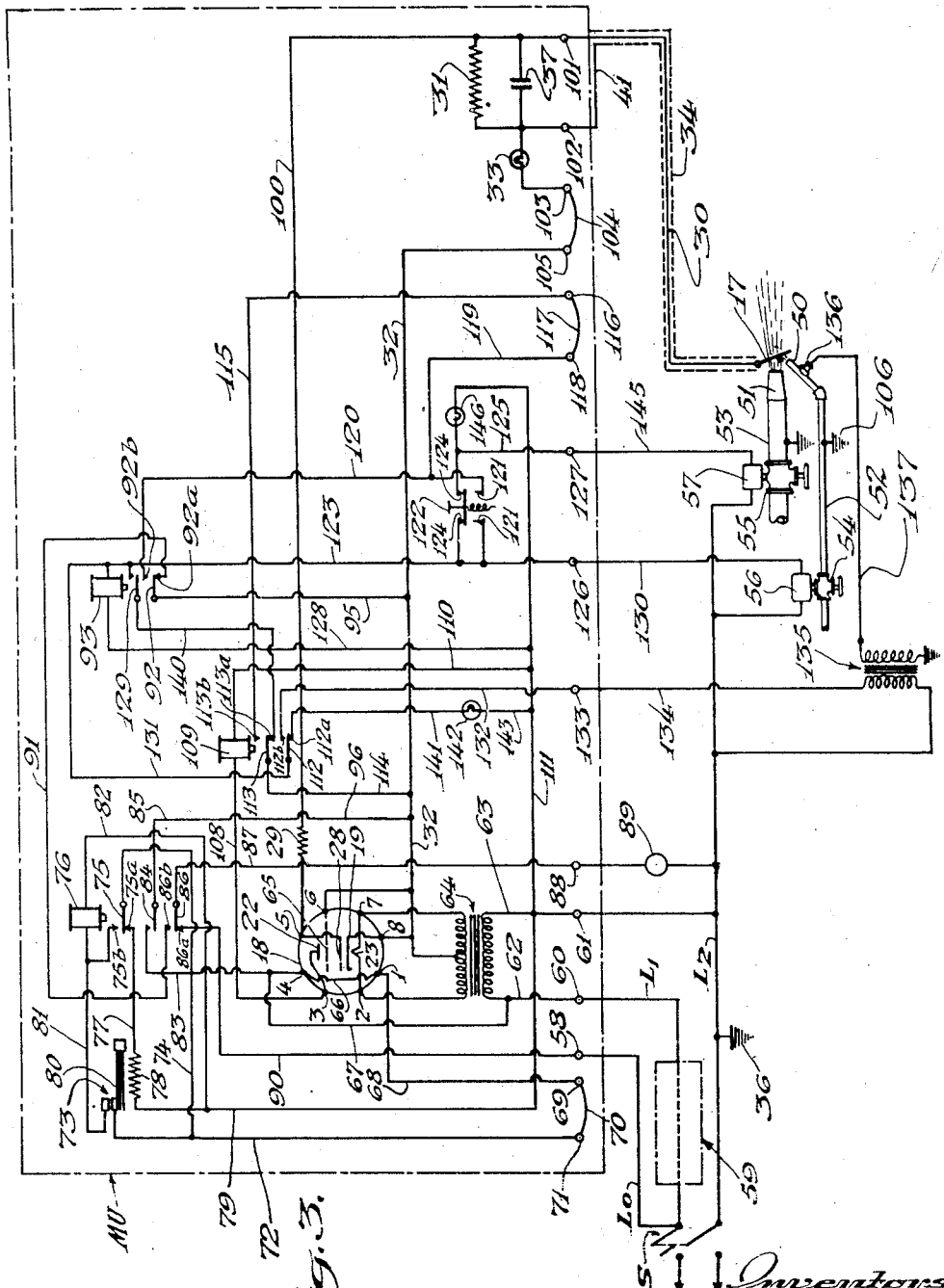


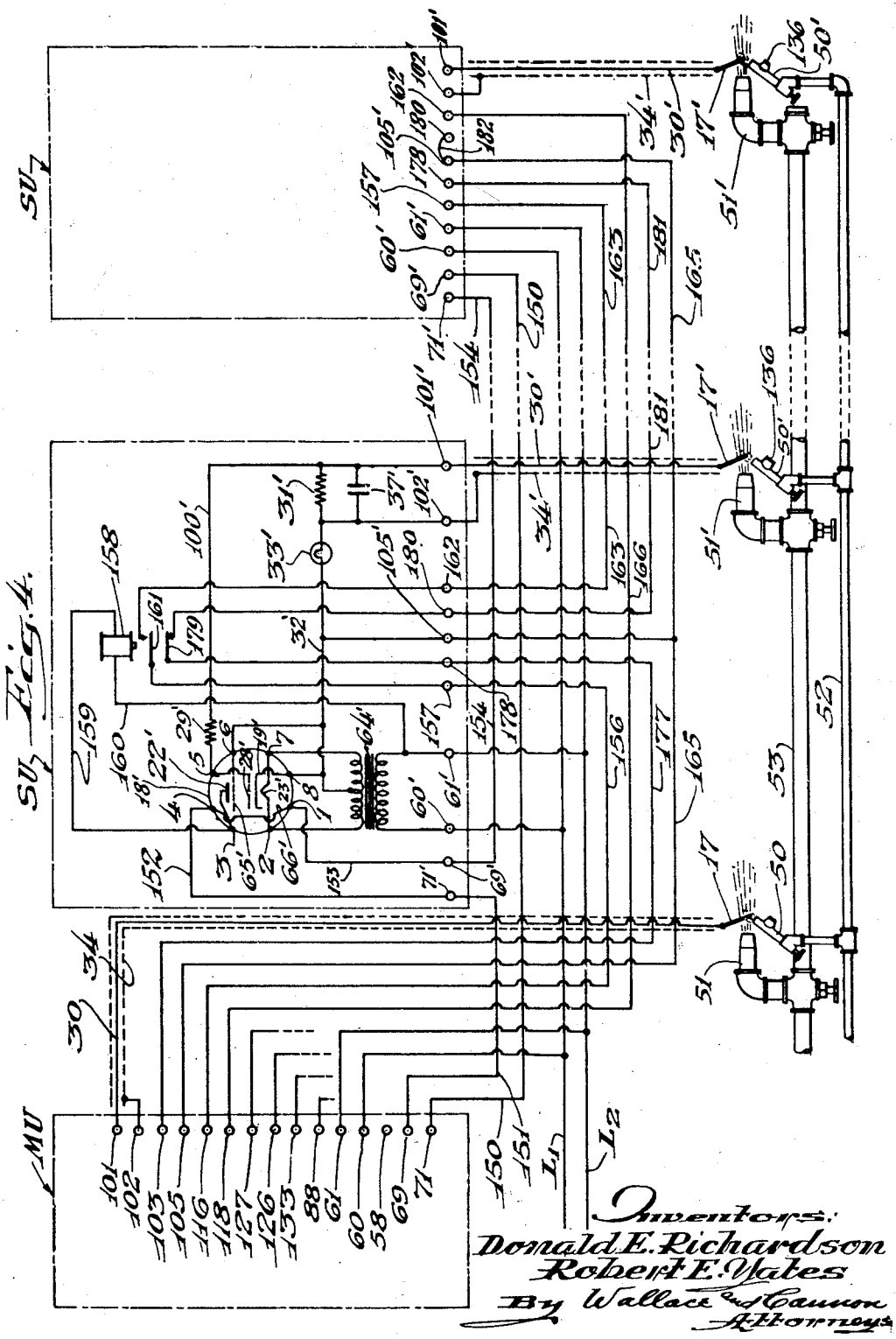
Fig. 3.

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BURNER SAFETY CONTROL

Filed June 28, 1941 6 Sheets-Sheet 3



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Nov. 5, 1946. D. E. RICHARDSON ET AL 2,410,524

BURNER SAFETY CONTROL

Filed June 28, 1941 6 Sheets-Sheet 4

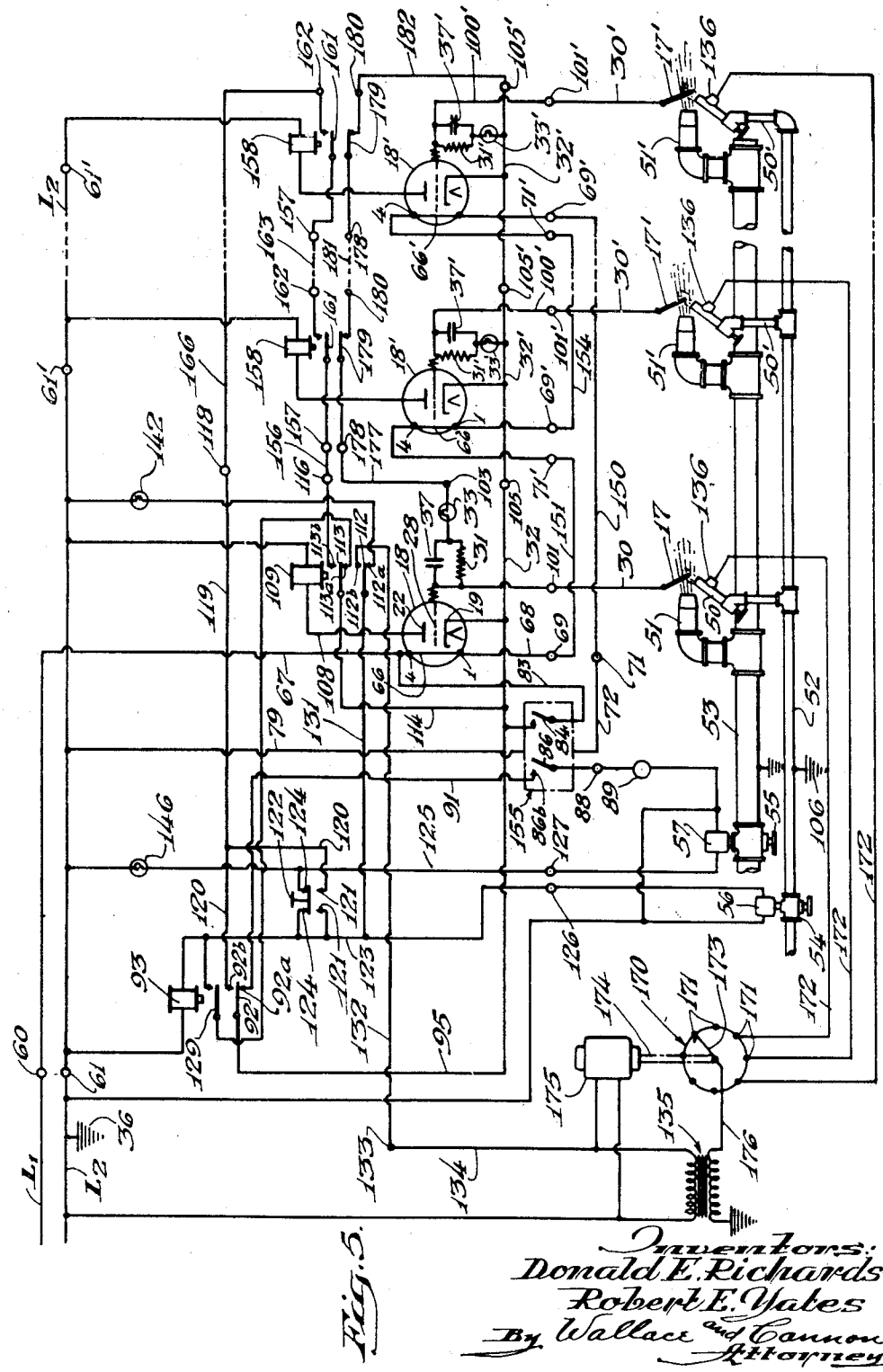


Fig. 5.

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Nov. 5, 1946. D. E. RICHARDSON ET AL 2,410,524

BURNER SAFETY CONTROL

Filed June 28, 1941 6 Sheets-Sheet 5

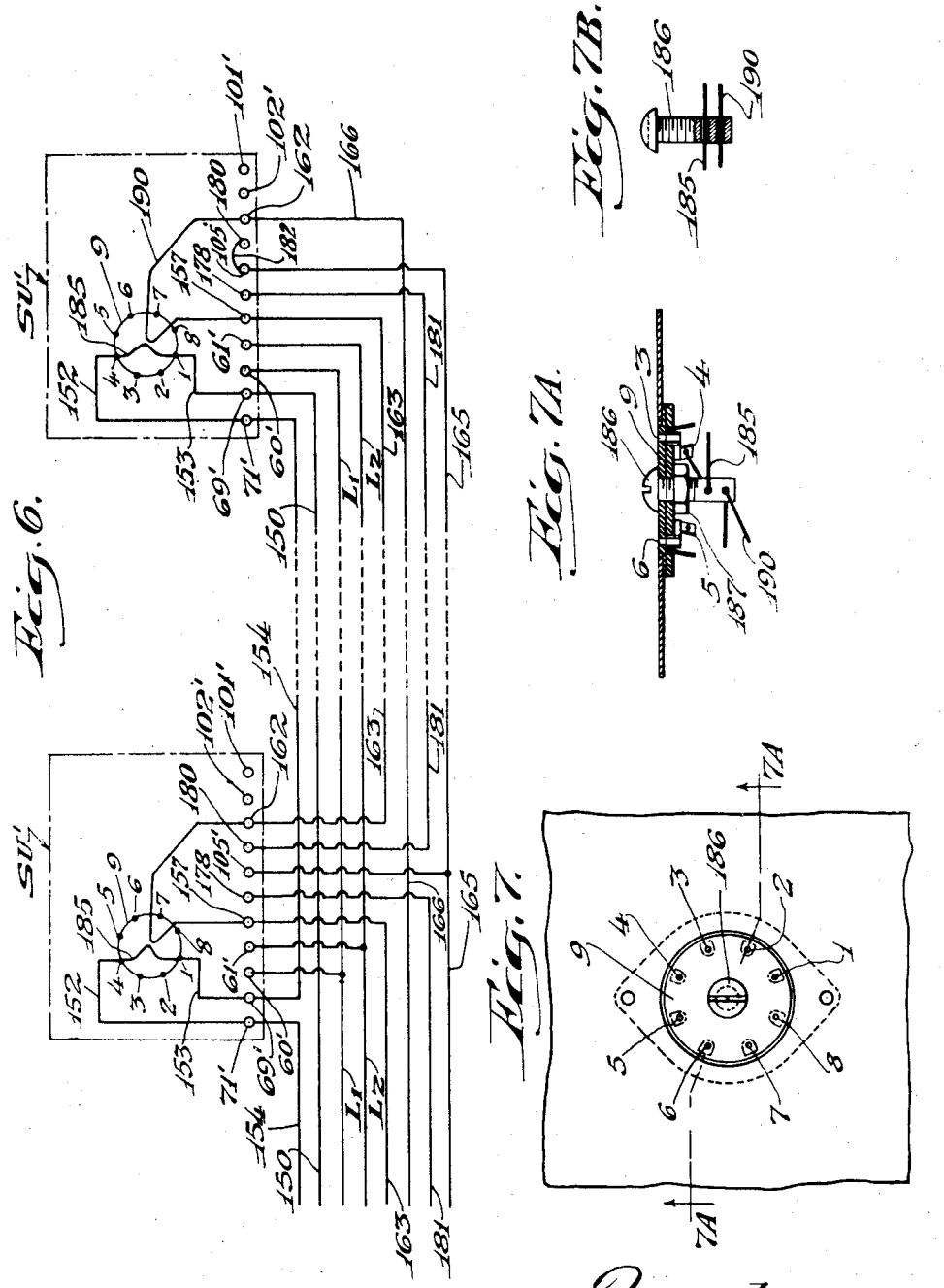


Fig. 6.

Fig. 7B.

Fig. 7A.

Fig. 7.

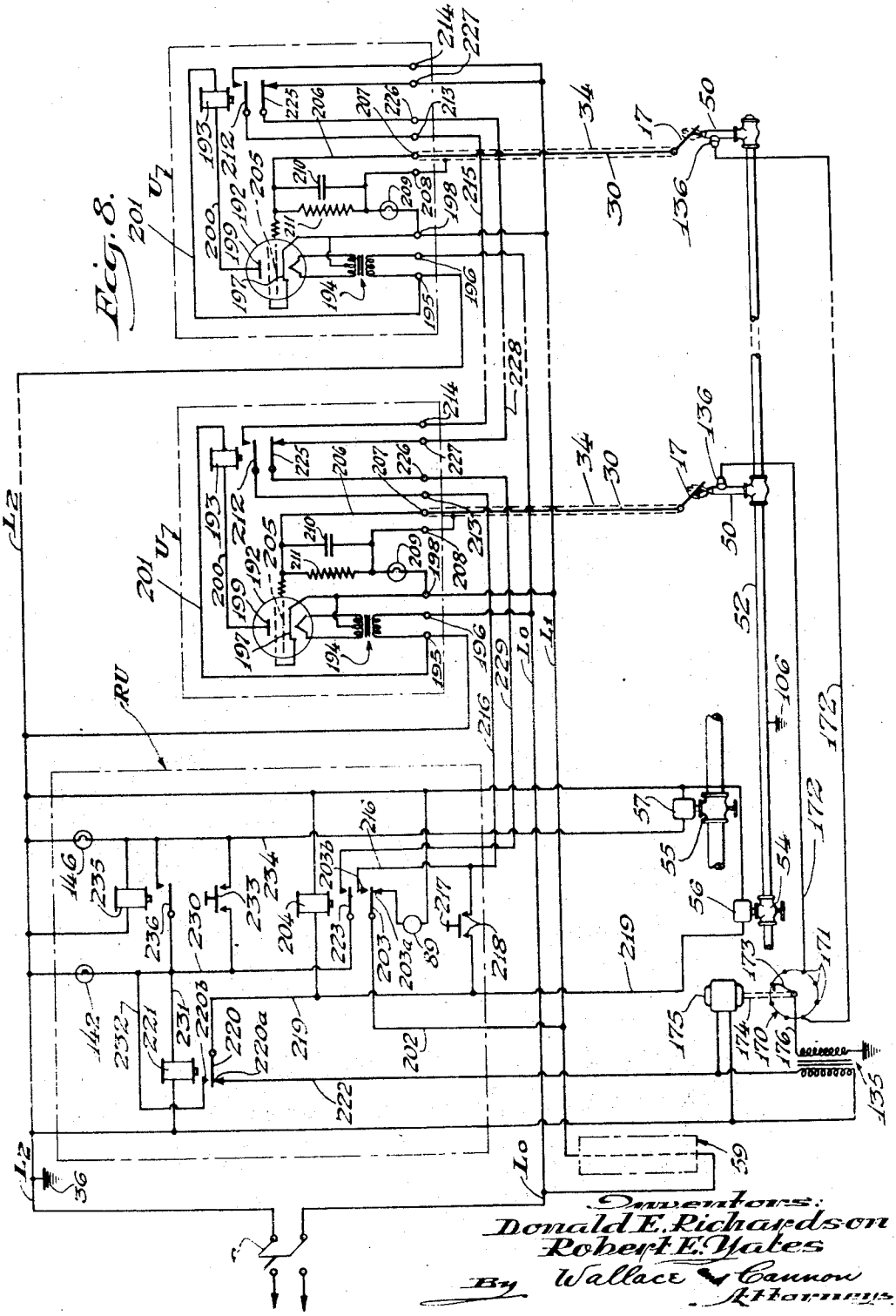
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BURNER SAFETY CONTROL

Filed June 28, 1941 6 Sheets-Sheet 6

Fig. 8.



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2,410,524

UNITED STATES PATENT OFFICE

2,410,524

BURNER SAFETY CONTROL

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Application June 28, 1941, Serial No. 400,332

16 Claims. (Cl. 158—28)

1

This invention relates to fuel burners and like heating devices and particularly to safety control apparatus for use with such devices.

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

2

these the electrical current flow through the flame path 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 the copending application of Robert E. Yates, Serial No. 245,173, filed December 12, 1938, now 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 electrodes 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 furnishes a false indication of the presence of a flame unless it 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 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 our 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 been 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.

In flame-detecting devices which embody electron tubes, particularly those of the gas-filled type, it is desirable to have the tube perform as little work as possible so as to prolong the life of the tube. Normally the control apparatus may well be in an idle condition and need be called upon to function only on comparatively rare occasions, as in the event of flame failure or upon the occurrence of some other hazardous condition against which the apparatus is designed to guard, and even then it need operate for only a short time. Hence, it is advantageous to so arrange the tubes that they remain nonconductive while the burner system is in normal operation, or in other words during the greater part of the time, and become conductive only in an emergency requiring operation of the control apparatus, and so to do is an object of a preferred form of the present invention.

Electronic safety control apparatus of the character in which an electron tube is adapted to be rendered nonconductive when the presence of a flame in the burner is sensed may become subject to misoperation due to internal failure of the tube. For example, the tube may become nonconductive due to burning out of the filament or because of other circumstances tending to decrease its conductivity so that the tube tends to give a false indication that a flame is present in the burner even though this may not actually be the case. In the aforesaid copending application, Serial No. 245,173, there is disclosed means for causing the apparatus to react safely in the event one or more electron tubes become defective due to filament failure. However, inasmuch as this is only one of the possible causes of tube failure, we have in the present instance provided means for automatically checking each electron tube to determine whether or

not it is capable of operating properly and to detect failure of the tube due to any of a number of causes. Preferably such checking of the tubes should take place prior to the initiation of operation of the heater system, and so to do constitutes another object of the invention.

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 specific object of a preferred form of the present invention is to so arrange an electron tube and a condenser in relation to an alternating current source and to the flame-sensing electrodes that the substantially unilateral conductivity of the electrical path through the flame normally enables the condenser to become unidirectionally charged during those half-cycles of the alternating current in which the tube is inoperative (that is, in the inverse half-cycles). An ancillary object is to so control the tube by the condenser that the tube remains continuously nonconductive if and when a substantial unidirectional charge exists on the condenser, whereby, if this charge is dissipated due to the establishment of a bilateral electrical connection between the flame-sensing electrodes, such as may be caused by a short circuit or a leakage shunt, or if this charge leaks off without being replenished because of flame failure, the tube becomes effective to conduct current during forward half-cycles of the alternating current.

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 we now consider to be the best mode in which we 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 present invention and the purview of the appended claims.

In the drawings,

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

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;

Fig. 3 is a schematic view of a master control unit embodying various improvements over the apparatus shown in Fig. 1;

Fig. 4 is a schematic view similar to Fig. 3 and showing another manner in which the apparatus may be incorporated in a multiple burner system;

Fig. 5 is a simplified wiring diagram of the apparatus illustrated in Figs. 3 and 4;

Fig. 6 is a diagrammatic view showing the manner in which spare control units may be provided;

Fig. 7 is a plan detail view of a tube socket as it is mounted in a control unit;

Fig. 7A is a sectional detail view taken substantially on the line 7A—7A on Fig. 7;

Fig. 7B is a partly sectional detail view of a screw shown in Fig. 7A; and

Fig. 8 is a diagrammatic view of a modified form of the invention.

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. We 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 we do not limit ourselves to such a tube since a vacuum tube may be utilized in lieu thereof if desired. The cathode 19 of the tube 18 is electrically connected to a line wire L1 which leads to one pole of a suitable source of alternating current. A line wire L2 leading from the other pole of said source of current is electrically connected to one end of the winding of a relay 20, the other end of this relay winding being connected by a conductor 21 to the anode 22 of the tube 18. The heater or filament 23 of the tube 18 is electrically connected to a suitable filament voltage supply source.

The relay 20 has a contact 24 which is normally closed when the relay is in a deenergized condition so as to establish an electrical connection from a conductor 25, which leads from one end of the winding of the fuel valve solenoid 16, to another conductor 26 that leads to one pole of a suitable source of voltage. The other pole of this source of voltage is electrically connected by a conductor 27 to the other end of the winding of the solenoid 16. Thus the solenoid 16 is maintained energized so long as the relay contact 24 is closed, and while it is in this condition it holds the fuel valve 15 open to enable the supply of fuel to the burner 12. However, if the relay contact 24 opens upon energization of the relay 20, the solenoid 16 is deenergized and the fuel valve 15 closes.

The voltage between the line wires L1 and L2 is of a sufficient value that it tends to cause the tube 18 to fire and conduct current during those half-cycles of the alternating current when the anode 22 is positive with respect to the cathode 19, thereby energizing the relay 20 and breaking the electrical connection between the conductors 25 and 26. However, as will be seen presently, the tube 18 is prevented from becoming conduc-

tive under normal conditions when there is combustion of the fuel in the burner, so that the relay 20 remains deenergized and thereby enables the fuel valve solenoid 16 to remain operative for maintaining the fuel valve 15 open.

Since the tube 18 is to be responsive to combustion conditions in the burner 12, means have been provided to control the operation of this tube in accordance with the presence or absence of a flame as F in the burner. Thus, the control element or grid 28 of the tube 18 is connected through the medium of a protective resistor 29 to a conductor 30 which is electrically connected to the flame-sensing electrode 17. This conductor 30 is also electrically connected by a resistor 31 to a conductor 41 which is connected by the filament of a lamp 33 to the wire 32 leading to the cathode 19 and line wire L1. In order to prevent stray electrical disturbances from affecting the tube 18, the conductor 30, which in ordinary practice is apt to be of considerable length, is enclosed in a metallic sheath 34 which is insulated therefrom throughout its length, this sheath 34 being electrically connected to the conductor 41. Usually the dielectric insulating medium between the conductor 30 and the sheath 34 affords a slight amount of electrostatic capacity, which has been diagrammatically represented in Fig. 1 as being lumped in a single capacitance 35, hereinafter referred to as a condenser.

In order to complete the flame-sensing circuit the line wire L2 is grounded as indicated at 36 so that whenever a flame F is present in the burner 12 an electrical circuit is established from line wire L2 through the burner 12, flame F, electrode 17, conductor 30, and through the resistor 31 and condenser 35 in parallel to the conductor 41, thence through the lamp 33 to the cathode return wire 32 which is electrically connected to the line wire L1. To augment the path afforded by the condenser 35 and resistor 31, another condenser 37 may be electrically connected across the conductors 30 and 41 in parallel with the resistor 31. Ordinarily the amount of current flowing through this flame-sensing circuit is so minute as to be incapable of lighting the lamp 33, except when certain kinds of short-circuits occur, as will be explained.

For the purpose of further protecting the device from stray electrical disturbances as well as to prevent accidental injury by electrical shock to persons working with the apparatus, the cable comprising the conductor 30 and sheath 34 may be passed through a conduit 38 which is grounded as indicated at 39, the sheath 34 being suitably insulated from this conduit. The presence of the sheath 34 intermediate the conductor 30 and grounded conduit 38 has a tendency to prevent excessive leakage through the insulation surrounding the conductor 30, inasmuch as this sheath is maintained at substantially the same potential as the line wire L1 and therefore tends to divert any leakage current proceeding from the line wire L2 by way of ground away from the conductor 30.

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. 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 is conductive only during those half-cycles of the alternating current in which the line wire L2 is positive with respect to the line wire L1, or in other words during the forward half-cycles. Under these conditions 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 electrode 17. During the inverse half-cycles, in which the polarities of the line wires L1 and L2 are reversed, the tube 18 is nonconductive but the flame F then conducts current. Under the latter circumstances, inasmuch as the line wire L1 is at positive potential with respect to the line wire L2, the condensers 35 and 37 are so charged that the grid 28 of the tube 18 assumes a negative potential with respect to the cathode 19. The full charge on these condensers may be built up throughout a series of inverse half-cycles, the length of time required to impart a substantially steady charge to these condensers being determined by the values of capacity and resistance in the circuit. Once the condensers have assumed their full charge, the grid 28 is imparted sufficient negative bias to prevent conduction of current through the tube 18. The resistor 31 has a high enough resistance so that the condenser charge is not appreciably diminished during the forward half-cycles so long as a flame F is maintained in the burner 12. Under these conditions the relay 20 remains in a deenergized state to thereby maintain an energizing circuit to the fuel valve solenoid 16, and hence fuel continues to be supplied to the burner 12.

If for some reason the flame F should become extinguished or unduly low, however, the above described flame-sensing circuit is broken and the condensers 35 and 37 discharge through the resistor 31, causing the grid 28 to lose its negative bias, and thereupon the tube 18 is rendered conductive during forward half-cycles of the alternating current. Hence, a pulsating rectified current passes through the winding of the relay 20, causing this relay to energize and open its contact 24. Preferably the relay 20 is of the slow-to-release type so that it maintains its contact 24 open so long as pulsating current is delivered to this relay winding by the tube 18. The energizing circuit for the fuel valve solenoid 16 is thereby broken, causing the fuel valve 15 to close and prevent any further supply of fuel to the burner 12.

For the purpose of initiating operation of the burner after it has been disabled by the safety apparatus a normally open starting 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 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 switch 40 and thereafter the valve energizing circuit is maintained closed through the contact 24 of the relay 20 (the tube 18 having been rendered nonconductive 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.

There are occasions in practice when the safety control apparatus is rendered partially defective by unwanted leakage or short-circuit conditions in the flame-sensing circuit. For example, the electrode 17 may accidentally come into contact with the burner 12 or to some other grounded part of the structure, or there may be a leakage path existing between the electrode 17 and burner 12 due to accumulation of carbon deposits or the like. Such a condition is undesirable because then current flow can take place between the electrode 17 and burner 12 independently of whether or not the flame as F is present. In the apparatus shown in Fig. 1, however, the safety control apparatus will respond in a safe manner under such circumstances. Thus, if there is a short circuit between the electrode 17 and the burner 12, the potential of the grid 28 becomes substantially the same as that of the line wire L2 so that the tube 18 is rendered conductive during forward half-cycles. Similarly, if there is a leakage path between the electrode 17 and burner 12, then because of the non-rectifying or bilateral character of this leakage path the condensers as 35 and 37 do not assume any appreciable unidirectional charge. Any charge which the condenser receives during the inverse half-cycle is generally lost during the succeeding forward half-cycle so that the grid 28 has no opportunity to retain its negative bias and therefore the tube 18 is rendered conductive to interrupt operation of the burner 12.

It should be noted in this connection that safe operation of the apparatus is insured even though the leakage resistance in the flame gap is of a value approximately equal to the ohmic resistance of a flame as F, and this is true even though the false flame resistance comes into being while the burner is in operation. In most instances where bilateral conduction through a leakage path occurs, the response of the apparatus is practically instantaneous. In other instances, where the leakage resistance is of a critical value, the apparatus may wait until there is an actual flame failure (if and when this occurs) before operating to shut off the fuel supply to the burner. In any event, however, the emission of unburned fuel is prevented, and it is not necessary as in the case of prior types of control apparatus to go through the process of recycling the system (that is, effecting a shutdown by other means and then starting the system in operation again) in order to so condition the apparatus that it will disable the fuel supply means upon detecting current leakage in the flame path.

Another undesirable condition may exist when there is excessive leakage or a direct short-circuit between the conductor 30 and the sheath 34, such as may be caused by a failure of the insulation. In this case the amount of resistance in parallel with the condensers 35 and 37 is greatly reduced so that these condensers discharge practically instantaneously during forward half-cycles of the alternating current, thereby rendering the tube 18 conductive with the effect aforesaid. There is also a possibility that the sheath 34 may become grounded, causing the filament of the warning lamp 33 to be connected directly across the line wires L1 and L2. This produces a relatively heavy flow of current through this filament, causing the lamp 33 to light. The tube 18 also becomes conductive due to the shunting of the condensers 35 and 37, and the relay 20 is thereupon energized to shut off the fuel supply.

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 28' of the electron tube 18' in the respective secondary unit SU. The shielded conductors 30 and 30' may be passed through individual grounded conduits such as 38, Fig. 1, or it may be preferred to run these conductors through a common conduit for at least a portion of their respective lengths. The secondary units are substantially identical in construction with the master unit MU except that they do not include any relays as 20, 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 respectively connected by conductors 21' to a common conductor 45 which is electrically connected to the anode 22 of the tube 18 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 32 and 32', respectively, to a common conductor 46 leading to the line wire L1. Hence, the electron tubes 18 and 18' in the various control units are all connected in parallel and the combined anode current of these tubes passes through the winding of the relay 20. The conductors 30' are connected through the medium of resistors 36' and condensers 37' to conductors 41', which are also connected to the sheaths 34', and from the conductors 41' electrical connections with the respective cathode return wires 32' are established through the filaments of lamps 33' embodied in the units SU.

It will be recalled that when a flame as F is present in a burner as 12 the associated tube as 18 is rendered nonconductive at all times. Similarly, when the flames are present in all of the other burners 12' the corresponding tubes 18' are all nonconductive, and under these circumstances the relay 20 remains deenergized. However, if a flame in any one of the burners becomes extinguished, or too low, the tube associated with such burner is rendered conductive so that current flow takes place in the common anode circuit including the windings of the relay 20, which relay thereupon energizes 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 contact 24, but

when the relay 20 is energized to open the contact 24 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. One of the advantages of arranging the electron tubes to be nonconductive under normal combustion conditions is that the relay 20 need merely be sensitive to any substantial current flow whatsoever in the common anode circuit. On the other hand, if the tubes were arranged to be conductive when flames were present in their corresponding burners, and nonconductive in the absence of flame, the relay 20 would be required to detect a proportional decrease in total anode current for each tube rendered nonconductive. In a multiple burner system having, say, sixteen burners and associated flame-detecting tubes, the operation of the relay 20 might become quite critical and on that account easily influenced by external factors such as fluctuating line voltages having no relation to the combustion conditions in the burners. Hence, we prefer that the electron tubes should be adapted to pass current only under abnormal conditions.

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 conductive to 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 with a minimum duplication of parts, it being noted that only one relay 20 and fuel valve 15 need be employed. The other portions of the apparatus such as electron tubes, resistors and condensers are relatively inexpensive so that the construction is quite economical in addition to being reliable.

It has been mentioned that another object of the present invention is to provide means for automatically checking the conductivity of the electron tube or tubes embodied in the safety control apparatus as a condition precedent to initiating operation of the fuel burner system, and to thereby insure that if any tube is defective so that it is unable to give an indication of flame failure, the system will be prevented from operating until a good tube has been substituted for the defective one. It is also desired to insure that the system will not function unless tubes which are especially adapted to be used in a safety control apparatus of this character are utilized in making tube replacements. A further object is to adapt the control apparatus for governing the operation of a burner system having both pilot burners and main burners. For the purpose of attaining these and other objects the type of apparatus illustrated in Figs. 3, 4 and 5 may be conveniently employed.

Referring first to Fig. 3, the control apparatus is there represented as comprising a master unit MU which is operatively associated with a burner system including a pilot burner 50 and a main fuel burner 51, these burners being supplied with fuel through separate supply pipes 52 and 53, respectively. The pilot burner 50 is so positioned with respect to the main burner 51 that a pilot flame originating in the burner 50 may ignite fuel issuing from the nozzle of the main burner 51. A flame-sensing electrode 17 is mounted in association with these burners in such a manner that it extends into the region of the pilot flame, and if gaseous fuel is being utilized in the main burner the electrode 17 may also pass through the main burner flame zone. However, if atomized liquid or pulverized solid fuel is being used in the main burner it may be preferable to arrange the electrode 17 so that it barely skirts the fringe of the main flame as it enters the pilot flame zone, thus minimizing the possibility of fuel gathering on the electrode and forming carbon accumulations thereon, while at the same time insuring that the pilot flame must be at least high enough to ignite the atomized or pulverized fuel in order that it may contact the electrode. The pilot and main burner fuel supply pipes 52 and 53 are respectively provided with fuel valves 54 and 55 which are operated by solenoids 56 and 57, respectively. When these solenoids are in a deenergized condition the fuel valves 54 and 55 are closed so that fuel is not supplied to the burners 50 and 51.

The application of the control apparatus shown in Fig. 3 to a burner system having a plurality of main burners and pilot burners will be explained subsequently in connection with Figs. 4 and 5, and for the present it will be assumed that the control apparatus comprises merely a master unit MU controlling a single main burner 51 and associated pilot burner 50. Electrical current is supplied to the apparatus by a suitable source of alternating-current voltage whenever the double-pole switch S is closed. One of the poles of the switch S is connected directly by a wire L0 to a terminal 58 on the control unit MU. The other pole of the switch S is connected to a wire L2 which serves as one of the line wires for the electrical system when the switch S is closed. The pole of the switch S to which the wire L0 is connected is likewise electrically connected to another line wire L1 through the medium of a preliminary control apparatus indicated by the rectangle designated 59, Fig. 3. Such preliminary control apparatus may comprise several forms of contact-making devices such as flow switches, time delay devices and the like which all serve the function of insuring that the heater in which the products of combustion from the burner 51 are to be utilized is first thoroughly scavenged and otherwise conditioned for operation before any combustion can take place. After the apparatus 59 has performed this function it causes an electrical connection to be established between the line wire L1 and the switch pole connecting with the source of electrical current.

The line wires L1 and L2 are respectively connected to terminals 60 and 61 on the control unit MU, and conductors 62 and 63 lead from these terminals to the primary winding of a transformer 64 included in the unit MU. The secondary of the transformer 64 supplies voltage to a filament 23 of the tube 18, this tube being similar to and performing the same function as the tube 18, Fig. 1. The tube 18 is provided with a shield grid 65 that is directly connected to the cathode 19 of the tube, and the cathode 19 is also electrically connected to the center tap on the secondary of the transformer 64.

An electron tube such as 18 of the character which we contemplate utilizing in the circuit of

Fig. 3 is customarily provided with eight prongs in its base, these prongs being adapted to be received in correspondingly positioned contacts afforded in a tube socket as 9, Figs. 7 and 7A. The various elements of the tube are internally connected to respective prongs, and electrical connection between these tube elements and the portions of the circuits external of the tube are established through the prongs of the tube and the contacts of the tube socket in which these prongs are received, the various external circuit conductors being soldered or otherwise suitably secured to the aforesaid contacts. In Fig. 3 the various tube socket contacts are diagrammatically represented as though viewed from the bottom and are designated 1 to 8, respectively. Ordinarily contact 1 is not used except when the tube is provided with an integral shield, in which event the shield is connected to the prong that fits into contact 1, which is in turn grounded. However, in the present instance the electron tubes which are to be employed in the apparatus are not shielded, or if they are shielded the shields are connected to ground in some manner other than through the No. 1 contact in the tube socket. The filament 23 is connected to the prongs that are received in contacts 2 and 7, across which the secondary of the filament transformer 67 is connected. The contacts numbered 3, 5 and 6 are respectively adapted to receive the prongs that are connected to the anode 22, control grid 28 and screen grid 65 of the tube 18.

For the purpose which will appear presently, we prefer to provide each tube 18 with a special jumper 66 which electrically interconnects the prongs of the tube 18 that are adapted to be received in the contacts 1 and 4 of the tube socket. If convenient, this jumper may be incorporated in the tube base in the course of manufacture thereof so that the two prongs to which the ends of the jumper are connected will be electrically in permanent connection with each other. The contact 4 of the tube socket is connected by a conductor 67 to the conductor 62 leading to the line terminal 60 of the control unit, while contact 1 is connected by a conductor 68 to a terminal 69 on the control unit MU. In the present instance, where only a single control unit is being employed, the terminal 69 is connected by a jumper 70 to a similar terminal 71 from which a conductor 72 leads to one contact of a thermal switch generally designated 73. A branch conductor 74 electrically connects the conductor 72 to a movable contact blade 75 of a relay 76 included in the control unit MU. When the relay 76 is in a deenergized condition the blade 75 engages a stationary contact 75a from which a conductor 77 leads to one end of the winding 78 of a heating element embodied in the thermal switch 73, the other end of this heater winding being connected by a conductor 79 to the conductor 63 which leads to the terminal 61 on the control unit MU.

When the line wires L1 and L2 are potentialized a predetermined time following closure of the switch S, a circuit is completed from wire L1 through the conductors 62 and 67, jumper 66 in the base of the tube 18, conductor 68, jumper 70, conductors 72 and 74, relay contact 75a and conductor 77 to the heater winding 78 and thence by conductors 79 and 63 back to the terminal 61 which is connected to the line wire L2. It is to be noted, however, that this circuit could not be established if a tube which was not equipped with a jumper as 66 had been used in lieu of a

tube as 18 shown in Fig. 3. This arrangement insures that the heater of the thermal switch 73 will not be energized unless a tube particularly adapted for use in the control unit MU is employed. It should also be noted that the line wire L1, which is not grounded, normally has a direct electrical connection with the contact 4 of the tube 18 and thence through the jumper 66 to contact 1, but if the jumper 66 is missing there is no electrical connection of the line wire L1 with the contact 1. Under the latter conditions the contact 1 is at substantially the same potential as the line wire L2, which is grounded as indicated at 36. (It will be understood, of course, that the wire L2 itself need not be grounded if the pole of the source of electrical current to which this wire is connected by the switch S is grounded.) Hence, if an operator should carelessly insert into the tube socket a tube having a shield electrically connected to the prong which fits into the No. 1 contact, but not being provided with a jumper 66, there is no danger that he will receive a shock, since the potential of the ungrounded or "hot" line wire L1 is not applied to the shield of the tube.

The purpose of the thermal switch 73 is to afford a preliminary warming-up period for the filament 23 of the tube 18 before any anode voltage is supplied to the tube, this being a precautionary measure to prevent damage to the tube. The heater 78 of the switch 73 starts to warm up concurrently with the filament 23, and after ample time has elapsed for the filament 23 to attain operating temperature, the bimetallic strip 80 of the switch 73 flexes and closes the switch to establish an electrical connection between the aforesaid conductor 72 and another conductor 81 that leads to one end of the winding of the relay 76, the other end of this relay winding being connected by the conductor 82 to the conductor 79 leading to the line wire L2. Closure of the switch 73 therefore causes relay 76 to energize, and in so doing the relay moves its contact blade 75 away from the contact 75a and into engagement with a contact 75b. The heater 78 of the switch 73 is thereupon deenergized and the bimetallic strip 80 thereafter cools off and separates the contacts of the switch 73. The contact 75b of the relay 76 is connected to the conductor 81 which leads to the winding of this relay, so that immediately upon energization of relay 76 a holding circuit is established from the conductor 72 through conductor 74 and contact 75b to the relay winding; hence opening of the switch 73 does not deenergize the relay 76, which remains locked up through the just described holding circuit. Thus the thermal switch 73 merely performs the function of initially energizing the relay 76 and is not called upon to operate continuously for holding the relay energized.

The relay 76 has another contact 84 which is normally open when this relay is in a deenergized condition, but when the relay 76 is energized in the manner just described the contact 84 closes and electrically connects a conductor 83 with another conductor 85 that is tapped onto the cathode return wire 32. The conductor 83 is electrically connected by the conductors 67 and 62 to the terminal 60 to which the line wire L1 is connected. Hence, so long as relay 76 is maintained energized, the cathode return wire 32 is potentialized by the line wire L1 through the medium of the closed relay contact 84.

When the switch S is first closed, a circuit is completed through the wire L0 to the terminal

58, thence through a conductor 90 to a stationary contact 86a of the relay 76, thence through a contact blade 86, which is normally engaged with the contact 86a, and a conductor 87 to a terminal 83 on the control unit MU. An alarm 89, which may be of either the visible or audible type, is connected on one side to the terminal 88 and on the other side to the line wire L2, and hence when the switch S is first closed the alarm 89 is energized from the wire L0 to thereby indicate that the preliminary scavenging operations referred to hereinabove have commenced. When the relay 76 is energized in the manner just described, however, there is a momentary interruption in the operation of the alarm 89 while the contact blade 86 of the relay moves out of engagement with the contact 86a and into engagement with the contact 86b. A conductor 91 connects the contact 86b to a contact 92a of another relay 93. A contact blade 92 is normally engaged with the contact 92a when the relay 93 is deenergized, and this blade 92 is connected by a conductor 95 to the cathode return wire 32 leading to the cathode 19 of the tube 18. Inasmuch as the wire 32 is potentialized by the line wire L1 upon energization of the relay 76, as just explained, the alarm 89 is maintained energized from this source until such time as the relay 93 becomes energized in a manner to be described.

The control grid 28 of the tube 18 is connected through a protective resistor 29 and a conductor 100 to a terminal 101 on the master unit MU, to which terminal the conductor 30 leading from the flame-sensing electrode 17 is connected exteriorly of the control unit. The sheath 34 enclosing the conductor 30 is electrically connected by a conductor 41 to a terminal 102 on the control unit MU, while the resistor 31 and condenser 37 (which perform functions analogous to those of the like-numbered parts in Fig. 1) are connected in parallel between the terminals 102 and 101. The terminal 102 is connected by the filament of a lamp 33 to a terminal 103, and in the present instance where there is but a single burner to be controlled, a jumper 104 interconnects the terminal 103 with another terminal 105 to which the cathode return wire 32 is connected. The pilot burner fuel pipe 52 is grounded as indicated at 106 so that an electrical connection between the grounded line wire L2 and the electrode 17 is afforded through the medium of a flame from the pilot burner 50 whenever such a flame is present.

During the preliminary operations which have been described thus far, the fuel valves 54 and 55 remain closed and no flame exists in either the pilot burner 50 or the main burner 51; hence no current flow can take place through the flame-sensing circuit including the electrode 17 and conductor 30. Inasmuch as no charge exists on the condenser 37 under these conditions, the control grid 28 of the tube 18 is at substantially the same potential as the cathode 19. Anode voltage is supplied to the tube 18 through a path comprising a conductor 108 which leads from the No. 3 or anode contact in the socket of the tube 18 to one side of the winding of a relay 109, this winding being connected on its other side by conductors 110 and 111 to the conductor 63 leading to the terminal 61 to which the line wire L2 is connected. It has been previously explained that the cathode 19 and its return wire 32 are connected to the line wire L1 when the relay 76 is energized; hence energization of this relay causes a voltage to be impressed across the anode 22 and cathode 19 and thus produces a flow of current through the tube 18. This current flows only during forward half-cycles of the alternating current, that is half-cycles in which the line wire L2 is positive with respect to the line wire L1, so that a pulsating direct current is passed by the tube 18. The relay 109 is a slow-to-release relay which energizes when such a pulsating current is sent through its winding and assumes a continuously operative condition so long as such current flow continues.

The relay 109 has a pair of movable contact blades 112 and 113 which are normally engaged with contacts 112a and 113a when the relay is deenergized, but upon energization of the relay these blades become separated from the contacts 112a and 113a and engage the contacts 112b and 113b. The blade 113 is connected by a conductor 114 to the cathode return wire 32 and the contact 113b is connected by a conductor 115 to a terminal 116 on the control unit MU. For single-burner operation the terminal 116 is connected by a jumper 117 to a terminal 118 on the control unit MU, which latter terminal is connected by a conductor 119 to another conductor 120 interiorly of the unit MU. The conductor 120 leads to one of a pair of spaced contacts 121 which are adapted to be bridged by the plunger of a push-button switch 122, the other of this pair of contacts 121 being connected to a conductor 123. Normally the plunger of the switch 122 is retracted into engagement with a pair of spaced contacts 124, one of which is connected to the conductor 123 and the other to a conductor 125, the conductors 123 and 125 being connected to terminals 126 and 127, respectively, on the control unit MU.

Assuming that the preliminary scavenging and like operations have been duly performed and that the tube 18 has become conductive to energize the relay 109, the operator manually depresses the push button 122 to thereby electrically connect the spaced contacts 121. Thereupon a circuit is completed from the cathode return wire 32 (which is connected to the line wire L1) through conductor 114, contact 113b of relay 109, conductor 115, jumper 117, conductor 119, contacts 121 and conductor 123 to the winding of relay 93, thence through this relay winding and conductors 128 and 111 to the line wire L2. Relay 93 is thus energized and closes a normally open contact 129 thereof, at the same time disengaging the contact blade 92 from the contact 92a and engaging this blade with the contact 92b that is connected to the aforesaid conductor 120. Disengagement of the blade 92 and contact 92a breaks the circuit to the alarm 89 and causes this alarm to cease operating.

Engagement of the blade 92 of the relay 93 with the contact 92b thereof closes a circuit from the cathode return wire 32 through conductor 95, contacts 92 and 92b, conductor 120, contacts 121 of the switch 122 (provided the plunger of this switch is maintained depressed by the operator) and conductor 123 to terminal 126 and thence exteriorly of the control unit MU through a conductor 130 to the winding of the solenoid 56 which operates the pilot fuel valve 54, this solenoid being connected on its other side to the line wire L2 to complete the circuit. A parallel circuit is likewise established under control of the switch 122, this circuit extending from the conductor 123 through a conductor 131 connected therewith, contact blade 112 and contact 112b of relay 109 (this relay still being in an energized condition)

and a conductor 132 to a terminal 133 on the control unit MU, and thence the circuit continues exteriorly of the unit MU through a conductor 134 to the primary of an ignition transformer 135 and from this primary winding back to the line wire L2. Thus the pilot fuel valve solenoid 56 and the ignition transformer 135 are concurrently energized when the push button 122 is depressed. The pilot burner 50 is equipped with a spark plug 136, the terminal of which is connected by a conductor 137 to one end of the secondary winding of the transformer 135, the other end of this secondary being grounded. High potential is thus applied to the spark plug as the pilot fuel valve 54 opens so that the fuel issuing from the pilot burner 50 may be ignited.

Upon the establishment of a pilot flame in the burner 50 electrical current commences to flow through the flame-sensing circuit, but due to the rectifying property of the pilot flame such current will flow between the electrodes 17 and the burner 50 only when the electrode 17 is positive with respect to ground potential. In other words, current flow through the pilot flame takes place only during those half-cycles when the line wire L1 is positive with respect to the line wire L2. The flame-sensing circuit is traced from the line wire L1 to the cathode return wire 32 in the manner described hereinabove, thence through the jumper 104, lamp 33, resistor 31 and condenser 37 in parallel (as well as through the dielectric insulating medium between the sheath 34 and conductor 30), flame-sensing electrode 17, and thence through the pilot flame to the pilot burner 50 which is electrically at the same potential as the line wire L2. However, during the half-cycle in which such current flow may take place through the flame-sensing circuit the tube 18 is inoperative inasmuch as the cathode 19 which is connected to the wire 32 is then positive with respect to the anode 22, which is connected through the winding of the relay 109 to the conductor 111 leading to the line wire L2. That is to say, the current flow through the flame takes place only during the inverse half-cycles of the alternating current, and therefore a rectified current flows through the condenser 37 as well as through the capacitance between the sheath 34 and conductor 30, the direction of this current flow being such as to cause the terminal 102 of the control unit MU to assume a potential which is positive with respect to that of the terminal 101. Terminal 102 is connected through the lamp 33, jumper 104 and wire 32 to the cathode 19 of the tube 18, while the terminal 101 is connected through the conductor 109 and protective resistor 29 to the control grid 28 of this tube; therefore, the grid 28 becomes negative with respect to the cathode 19 due to the unidirectional charge which accumulates on the condenser 37.

The charge on the condenser 37 (which will hereinafter be assumed to include the capacity of the insulation between the conductor 30 and sheath 34) may continue to build up throughout a plurality of inverse half-cycles until a substantially steady-state condition is attained so long as a flame is present in the burner 50. During forward half-cycles of the alternating current, when the relative polarities of the line wires L1 and L2 are such that the anode 22 of the tube 18 is positive with respect to the cathode 19, the charge on the condenser 37 is slightly diminished but remains at a sufficiently high level to maintain the potential of the control grid 28 of the tube 18 appreciably negative with respect to that of the cathode 19, and whatever charge leaks off of the condenser 37 during such forward half-cycles is regained during the succeeding inverse half-cycles. Hence, the tube 18 is prevented from conducting current so that current flow ceases in the anode circuit including the winding of the relay 109. The relay 109 therefore deenergizes, causing its contact blades 112 and 113 to separate from the contacts 112b and 113b and reengage the contacts 112a and 113a, respectively, one of the results of this being that the circuit to the primary of the ignition transformer 135 is broken and the spark plug 136 is deenergized. Also, the electrical connection between the conductors 114 and 115 is broken so that the contact 121 of the switch 122 which is connected to the conductor 120 is no longer connected to the cathode return wire 32 through the path including the conductors 119, 115 and 114. However, when the relay 93 was energized in the manner hereinabove explained, a circuit was closed from the wire 32 through conductor 95, contacts 92 and 92b of the relay 93, and conductor 120 to the just-described contact 121 of the switch 122. Hence, so long as the relay 93 remains energized the energizing circuit to the pilot fuel valve solenoid 56 continues, providing the push button 122 is held depressed.

The relay 93 may be maintained energized through two possible holding circuits, one of these being traced from the cathode return wire 32 through the aforesaid contacts 92 and 92b of the relay 93, conductor 120, contacts 121 of the switch 122 and conductor 123 to the winding of the relay 93. The other holding circuit is established when the contact blade 113 of the relay 109 engages the contact 113a upon deenergization of this relay, this circuit being traced from the cathode return wire 32 through the conductor 114, contacts 113 and 113a, a conductor 140, contact 128 of the relay 93 (this contact being closed so long as the relay 93 is energized, conductor 123, winding of relay 93 and conductors 128 and 111 to the line wire L2. The relay 93 remains locked up through this latter holding circuit so long as relay 109 remains deenergized. During the interim while the blade 113 of the relay 109 is traversing the gap between the spaced contacts 113b and 113a upon deenergization of the relay 109, the relay 93 is held energized solely through the first-mentioned holding circuit including the contacts 92 and 92b of the relay 93 and the contacts 121 of the push-button switch 122, and hence there is no interruption of the circuit through which the pilot fuel valve solenoid 56 is held energized. The same result could be obtained without the use of this manually controlled holding circuit by arranging the contacts 113a and 113b of the relay 109 in a make-before-break manner so that the blade 113 engages the contact 113a prior to disengaging the contact 113b. However, in the present instance it is preferred not to employ make-before-break relay contacts but instead to utilize the manually controlled holding circuit for the aforesaid purpose.

To summarize the foregoing operations, the establishment of a pilot flame in the burner 50 causes the tube 18 to cease conducting current and brings about deenergization of the relay 109, as an incident to which a holding circuit is established for maintaining the relay 93 energized so long as relay 109 remains deenergized. As can

be seen from Fig. 3, the establishment of this holding circuit also serves to maintain the conductor 123 at the same potential as the cathode return wire 32 which is electrically connected to the line wire L1, so that the pilot fuel valve solenoid 56 is held energized. As the relay 109 deenergizes and closes its contact 112a, a circuit is completed from conductor 123 through conductor 131 and the contact 112a to the conductor 141 leading to a lamp 142 and thence through the filament of this lamp and conductors 143 and 111 to the line wire L2. The lamp 142 thereupon lights to indicate that a holding circuit has been established by the relay 109 for the relay 93 and the pilot fuel valve solenoid 56. Upon observing this indication the operator releases the push button 122, and the plunger of the switch is thereupon restored to break the electrical connection between the contacts 121 and reestablish the connection between the contacts 124. This results in automatically closing a circuit from the conductor 123 through the contacts 124 and conductor 125 to the terminal 127 and thence through the conductor 145 and the winding of the solenoid 57, which controls the main fuel valve 55, back to the line wire L2. The solenoid 57 energizes and opens the valve 55 to admit fuel to the main burner 51, and as the fuel issues from the burner 51 it is ignited by the pilot flame from the burner 50 and thus the operation of the heater is initiated. As an incident to this a lamp 146, which is connected across the conductors 125 and 111, lights to thereby indicate that the main burner 51 is in operation.

If for any reason there should be a failure of the pilot flame, or if this flame becomes too low or is otherwise rendered ineffective to ignite the fuel discharged from the nozzle of the main burner 51, so that there is an interruption of the electrical connection through the flame between the electrode 17 and the pilot burner 50, rectified current ceases to flow in the flame-sensing circuit and the condenser 37 thereupon loses its charge. The potential of the control grid 28 of the tube 18 is thus brought to approximately the same level as that of the cathode 19, and the tube 18 is thereupon rendered effective to pass current during the forward half-cycles. This results in energization of the relay 109, as an incident to which the lamp 142 is extinguished and the holding circuit for the relay 93 is broken, causing this relay to release and also bringing about the deenergization of the pilot valve solenoid 56, main valve solenoid 57 and lamp 146. As the relay 93 is deenergized, the blade 92 thereof engages the contact 92a and thereby closes circuit to the alarm 89, whereupon the alarm operates to give warning of what has happened.

The valves 54 and 55 close when the solenoids 56 and 57 are deenergized to thereby interrupt the admission of fuel to the burners 50 and 51. In order to start the burners in operation again, it is necessary to repeat the above described steps commencing with actuation of the starting switch 122 and culminating in the opening of the main fuel valve 55. If combustion conditions in the heater are favorable so that the fuel issuing from the burners 50 and 51 is properly ignited, the system operates automatically to continue the supply of fuel to these burners unless and until another abnormal condition arises.

It is to be noted from the foregoing that in the process of initiating operation of the main burner 51 the tube 18 must initially be in a conductive condition for energizing the relay 109 and thereby enabling the relay 93 and pilot valve solenoid 56 as well as the ignition transformer 125 to become energized when the push button 122 is depressed, after which the tube 18 becomes nonconductive upon the establishment of a pilot flame and deenergizes the relay 109 to enable the main valve solenoid 57 to become energized when the push button 122 is released. Thus, if there is an internal failure of the tube 18 which causes this tube to be permanently nonconductive or substantially so, the pilot fuel valve 54 is prevented from opening. On the other hand if the tube 18 fails in such a manner that it is permanently conductive, it will be possible to open the pilot fuel valve 54 but the main fuel valve 55 will be prevented from opening because of the fact that the relay 109 cannot be deenergized. In either event the operator is duly apprised of the situation from an observation of either the burners themselves or the indicating lamps 142 and 146, and he may then shut down the system entirely by opening the switch S to enable a check to be made.

As in the case of the previously described embodiments of the invention, it is desirable to check the system for abnormal conditions other than failure of combustion which may be a source of danger, and particularly to automatically detect any defective conditions in the flame-sensing circuit. Thus, for example, the electrode 17 may become deformed so that it engages the burner 50 or 51 and is thus connected directly to ground, that is to say, to the line wire L2. This causes the grid 28 to be positive with respect to the cathode 19 during forward half-cycles, and hence the tube passes current to energize the relay 109 and thereby interrupt operation of the burners 50 and 51 in the manner hereinabove explained. Similarly, if a non-rectifying or bilateral leakage resistance is established between the electrode 17 or conductor 30 and ground, such as may be caused by carbonization of the electrode 17 or failure of the insulation around the conductor 30, this nullifies the current-rectifying action of the flame and causes an alternating current to pass through the condenser 37. On alternating current the condenser 37 acts more or less as a shunt and is not likely to build up any appreciably steady charge; or in other words, any charge which is imparted to this condenser during an inverse half-cycle may be lost during the succeeding forward half-cycle. This results in rendering the system inoperative in the same manner as though there had been a flame failure or ground-out condition, the fuel supply either being interrupted immediately or being prepared for interruption in the event of a flame failure, depending upon the value of the leakage resistance. Likewise, failure of the insulation between the conductor 30 and the sheath 34 so as to establish a low-resistance leakage path in shunt with the condenser 37 renders this condenser ineffective to bias the control grid 28, with the above described results.

If more than one set of pilot and main burners is included in the burner system it is advantageous to have the fuel supply to all of the burners controlled by a single master unit MU, the operation of which is in turn partially controlled by one or more secondary units SU, Fig. 4, the master unit MU being allocated to one of the main burners 51 and its associated pilot burner 50 and each secondary unit SU being likewise allocated to a respective main burner 51' and pilot burner 50'. The secondary units SU are of identical construction with respect to each other

but are greatly simplified as compared with the master unit MU. Thus, referring to Fig. 4, each secondary unit SU includes a tube 18' which is identical with the tube 18 of the master unit MU, Fig. 3, and which functions in a corresponding manner. Each unit SU may include an individual filament transformer 64', the primary of which is connected across the line wires L1 and L2, but it is to be understood that a single transformer 64, Fig. 3, may be utilized to supply current for heating all of the tube filaments. Each tube 18' is provided with a jumper 66' which is electrically connected to the prongs that are received in the tube socket contacts 1 and 4 as in the case of the tube 18, Fig. 3.

When the master unit MU is to be operated in conjunction with one or more secondary units SU the jumper 70 between the terminals 69 and 71, Fig. 3, is omitted and a conductor 150, Fig. 4, leads from the terminal 71 of the master unit MU to the terminal 69' on the last secondary unit SU in the series. A conductor 151 connects the terminal 69 of the master unit MU to the terminal 71' of the first secondary unit SU in the series. Interiorly of this secondary unit a conductor 152 leads to the No. 4 tube socket contact, and if a tube 18' properly equipped with a jumper 66' is received in the tube socket the circuit continues from the conductor 152 and the No. 4 contact through this jumper 66' to the No. 1 contact and thence through a conductor 153 to the terminal 69' on the secondary unit SU. A conductor 154 then leads from this terminal 69' to the terminal 71' on the next secondary unit SU in the series or if there is only one other secondary unit SU, this conductor 154 is connected to the terminal 71' of such unit. If there are more than two secondary units SU the terminal 69' of each such unit is connected by a conductor as 154 to the terminal 71' on the next unit, except for the last unit SU in the series, the terminal 69' of which is connected to the conductor 150 leading back to the terminal 71, Figs. 3 and 4, of the master unit MU. As a result of these connections, if the proper type of tube 18' has been installed in each secondary unit SU, a series circuit is established through the jumpers 66 and 66' of the tubes 18 and 18' in the master and secondary units, as can be seen by reference to the simplified circuit diagram in Fig. 5. This series circuit connects the line wire L1 with the conductor 72 leading to the time delay device generally designated 155 in Fig. 5, this device 155 comprising the thermal switch 73 and relay 76, Fig. 3, which are wired up in the manner shown in the latter view. The circuit then continues through the heater element and relay winding of the device 155 and through a conductor 79 back to the line wire L2.

When the conductors L1 and L2 are potentialized, assuming that the aforesaid series circuit has been established, the filaments of the tubes 18 and 18' immediately commence to heat up during the time delay interval which is afforded by the action of the device 155, Fig. 5. At the expiration of this interval the device 155 closes its contact 84, thereby connecting the cathode return wire 32 to the conductor 67 which is connected to the line wire L1, and thus applying the potential of the line wire L1 to the cathode return wire 32. The device 155 likewise shifts its contact blade 86 into engagement with the contact 86b to thereby close a circuit from the wire 32 through the alarm 89 to the line wire L2 for maintaining the alarm 89 energized so long as the relay 93 remains deenergized.

Each secondary unit SU has a relay 158, the winding of which is connected on one side by a conductor 159 to the No. 3 or anode contact of the tube 18' in said unit, Fig. 4, and on its other side by a conductor 160 to the terminal 61' which is electrically connected to the line wire L2. Thus, the relay 158 is included in the anode circuit of the tube 18' to be energized whenever the tube 18' is rendered conductive. Terminals 105' of all the secondary units SU are electrically connected to the cathode return wires 32' of their tubes 18' and are electrically connected exteriorly of the secondary units SU to a common conductor 165 which leads back to the terminal 105 of the master unit MU, Fig. 3. Thus, referring to Fig. 5, the cathodes of the tubes 18 and 18' are simultaneously potentialized when the relay device 155 connects the cathode return wire 32 of the master unit MU with the line wire L1.

The control grids 28' of the tubes 18' in the various secondary control units SU, Fig. 4, are respectively connected to the flame-sensing electrodes 17' associated with the pilot burners 50' to which the units SU are respectively allocated. When a pilot flame is present in a particular burner 50' a circuit is established from the line wire L2, Fig. 5, through said burner 50' and the path afforded by the pilot flame to the associated electrode 17', thence through the conductors 30' and 100' and the resistor 31', condenser 37' and lamp 33', Figs. 4 and 5, included in that particular control unit SU to the cathode return wire 32', from which point the circuit is completed through the common conductor 165 and wire 32 in the master unit MU to the line wire L1. Rectified current flowing through such circuit builds up a charge on the condenser 37' included therein so that the associated tube 18' is biased to the point where it is nonconductive. However, when a flame is absent in the particular pilot burner 50' the tube 18' is rendered conductive and passes current through its anode circuit to energize the relay 158.

Referring again to Figs. 3 and 4, the relay 109 in the anode circuit of the tube 18 in the master unit MU has a contact 113b which is connected to a terminal 116 on the master unit MU. For multiple burner operation the jumper 117, Fig. 3, is omitted and a conductor 156, Fig. 4, is employed to connect this terminal 116 to a terminal 157 on the first of the secondary units SU in the series. The relay 158 in this secondary unit has a contact 161 which is normally open when the relay is deenergized but which closes when the relay is energized, in a manner presently to be explained, to electrically connect the terminal 157 on the secondary unit SU to a terminal 162 on said unit. The terminal 162 is connected by a conductor 163 to the terminal as 157 of the next secondary unit SU, and the terminal as 162 of this unit is in turn connected by another conductor 163 to the terminal as 157 of the next succeeding secondary unit as SU, and so on until the last of the secondary units SU in the series is reached. The terminal 162 of this last unit is connected by a conductor 166 to the terminal 118 of the master unit MU, Figs. 3 and 4. Thus, referring to Fig. 5, all of the relays 109 and 158 in the various control units must be energized in order to establish an electrical connection between the conductors 114 and 119, Figs. 3 and 5.

Before operation of any of the burners can be initiated the tubes 18 and 18' must all be ren-

dered conductive, and if the tubes are all in working condition they will automatically become conductive as soon as the cathode return wires 32 and 32' are potentialized inasmuch as there is no substantial bias on the control grids of these tubes in the absence of flames in the associated burners. Assuming that all of the tubes are in good condition so that the relays 109 and 158 in their anode circuits become energized, a series circuit is completed from the cathode return wire 32 of the master unit MU, Fig. 3, through the conductor 114 and the contact 113b of the relay 109 and thence through the contacts 161 of the relays 158 to the conductor 156, Figs. 4 and 5, leading back to the conductor 119, Figs. 3 and 5, which is connected to the conductor 120 leading to a contact 121 of the switch 122. The system is thereupon conditioned to become operative when the button of the switch 122 is pushed.

As has been described hereinabove, the switch 122 is manually actuated to energize the pilot fuel valve solenoid 56 and the ignition means. In the present instance, where a plurality of pilot burners are to be ignited, it is advantageous to employ a distributor 170, Fig. 5, having a number of contact segments 171, each of which is connected by a conductor 172 to a spark plug 136 on a pilot burner 50 or 50'. The distributor 170 has a wiper 173 insulatedly mounted on the shaft 174 of a motor 175. The motor 175 is connected in parallel with the primary of the ignition transformer 135, while the high potential terminal of the transformer secondary is electrically connected by a conductor 176 to the wiper 173 of the distributor 170. The motor 175 is energized and commences rotating the wiper 173 simultaneously with the energization of the ignition transformer 135 and the opening of the pilot fuel valve 54. As the wiper 173 successively engages the contacts 171, the spark plugs 136 are energized in rapid succession for igniting the fuel in the various pilot burners 50 and 50'. By employing such a distributor arrangement, it is possible to utilize a single ignition transformer which need only be capable of energizing a single spark plug at a time, and on the whole a more satisfactory and economical operation is insured than would be the case if a separate ignition transformer were provided for each burner or if a single transformer were arranged to supply potential to a number of spark plugs in parallel.

As each pilot burner 50' is ignited a rectified current flow is established in the flame-sensing circuit associated with such pilot burner, and in the manner explained hereinabove, this causes the corresponding tube 18' to become nonconductive, thereby causing the relay 158 in the anode circuit of such tube to deenergize. In the present instance, however, it is desirable that the relay 109, Figs. 3 and 5, in the anode circuit of the tube 18 of the master unit MU remain energized at least until all of the tubes 18' in the secondary units SU have been rendered operative in response to the establishment of pilot flames in their corresponding burners 50', regardless of whether the flame in the pilot burner 50 associated with the master unit MU has been established, for so to do insures that the holding circuit for the relay 93 and pilot valve solenoid 56 will not be established, nor will the ignition transformer 135 and motor 175 be deenergized, at least until flames are present in all of the pilot burners 50'.

For the purpose of delaying the response of the master unit MU to the establishment of a pilot flame in the burner 50 until the last of the pilot flames in the burners 50' has come into existence, the jumper 104 between the terminals 103 and 105 of the master unit MU, Fig. 3, is omitted and the terminal 103 is connected by a conductor 177 to a terminal 178 in the first of the series of secondary units SU. The terminal 178 on this unit SU is electrically connected by a contact 179 of the relay 158 to another terminal 180 on this unit whenever the relay 158 is in a deenergized condition, but when the relay is energized this connection is broken. The terminal 180 of the secondary unit SU is connected by a conductor 181 to the terminal 178 on the next secondary unit SU in the series until the last of the secondary units SU is reached. The terminal 180 of this last unit is connected by a jumper 182 to the terminal 105' to which the common conductor 106 is connected.

Thus, referring to Fig. 5, an electrical connection between the terminals 103 and 105 of the master unit MU, Fig. 3, is not established until all of the relays 158 in the secondary units SU, Fig. 4, have been deenergized to close their contacts 179; that is to say, the flame-sensing circuit of the master unit MU does not become effective until flames have been established in all of the pilot burners 50' to render all the tubes 18' in the secondary units SU nonconductive. Thereupon the flame-sensing circuit of the master unit MU is rendered effective, and if a flame is present in the pilot burner 50 the tube 18 becomes nonconductive to deenergize the relay 109. The relay 109 closes its contact 113a and thereby establishes a holding circuit for the relay 93 and the pilot fuel valve solenoid 56, at the same time opening its contact 112b to disable the ignition means including the transformer 135 and motor 175. The lamp 142 flashes on as the relay 109 closes its contact 112a to indicate that the push button 122 may be released to initiate operation of the main burners 51 and 51' in the manner previously explained.

If an abnormal condition should arise at any of the burners with which the secondary units SU, Fig. 4, are associated, such as a failure of combustion in such burner, the tube 18' in the secondary unit SU becomes conductive and energizes its relay 158. As this relay energizes it opens its contact 179 and thereby breaks the flame-sensing circuit for the master unit MU. This causes the tube 18 in the master unit MU to pass current and thereby energize the relay 109, causing the relay contact 113a to open and break the holding circuit for the relay 93, which in turn results in deenergizing the fuel valve solenoids 56 and 57, thus interrupting operation of all of the burners in this system. If the abnormal condition should arise at the burner with which the master unit MU is associated, then the tube 18 is immediately rendered conductive with the effect just described. It is manifest that the apparatus will function in a safe manner for any of the abnormal conditions referred to hereinabove, such as ground-out or leakage effects, as well as for a failure of combustion. It should also be noted that if any of the cable sheaths 34 or 34' becomes grounded, the associated warning lamp 33 or 33' lights to indicate the location of the fault.

While the master unit MU and secondary units SU have been described hereinabove as constituting separate control units which may be mounted in individual cabinets that are wired together by external connections and independently located with respect to each other, it is to be understood that these various control units may be embodied

in a single cabinet, and instead of being physically isolated from each other they may be assembled with their corresponding parts juxtaposed or otherwise arranged in any convenient manner. In such an event there would be no distinct control units, in the sense in which they have been referred to hereinabove, but there would be a series of control positions represented by the various tube sockets, each position having its associated circuit elements and wiring, somewhat as indicated in Fig. 5, to correspond to the respective fuel burners. However, for the sake of convenience and clarity the various control positions are regarded herein as though they consist of separate and distinct control units whether or not this is actually the case.

In the form of construction in which all of the control units are embodied in the same cabinet or housing it may be desired to include therein a greater number of control units than are actually needed for immediate service, in contemplation that additional burners may be added on to the system in the future, thus requiring additional active control units. Those control units which are not immediately utilized constitute spare units which are wired up with the other control units in such a manner that they may be expeditiously incorporated into the system when the need so to do arises. In this way it is possible to standardize the construction of the control cabinets with regard to the number of control units embodied therein, so that a special cabinet need not be made up for each individual customer nor is any rewiring of the cabinet required when a change is to be made in the number of active control units.

Referring to Fig. 6, each spare unit SU' is of substantially the same construction as the secondary unit SU shown in Fig. 4 and is wired in with the other control units in the system in substantially the same manner, these spare units SU' preferably being located at the end of the series of active secondary units, in which event the last of the active secondary units SU, Fig. 4, is connected to the first of the spare units SU', Fig. 6, in the same manner as the other active secondary units SU are connected to each other. Thus, a conductor 154 leading from the terminal as 69' of the last active unit SU is connected to the terminal 71' of the first spare unit SU'. The terminal 69' of this unit SU' is connected by another conductor 154 to the terminal 71' of the next spare unit SU', and so on until the last of these spare units SU' is reached, the terminal 69' of this last unit being connected to the conductor 150, Figs. 4 and 6. The filament transformer terminals 60' and 61' of the spare units SU' are respectively connected to the line wires L1 and L2, assuming an individual transformer for each control unit. The cathode return terminals 105' of the units SU' are connected to the common conductor 165 in the same manner as in the case of the active units SU, Fig. 4. The terminal 157 of each unit SU' is connected by a conductor 163 to the terminal 162 of the preceding control unit, and the terminal 162 of the last spare unit SU' is connected to the conductor 166. Likewise, the terminal 178 of each spare unit SU' is connected to the terminal 180 of the preceding unit, and the terminal 180 of the last unit SU' is connected by the jumper 182 to the terminal 105' of this unit.

The spare units SU' are not ordinarily equipped with tubes as 18', Fig. 4, and for that reason some means must be provided to afford continuity of the series circuit extending through the jumpers 66 and 66' of the tubes 18 and 18', Figs. 3, 4 and 5. Hence, a special insulated jumper 185 is connected between the No. 1 and No. 4 contacts of the tube socket 9 in each spare unit SU', this connection being indicated as though viewed from the bottom of the socket in Fig. 6. Of course, when a spare unit SU' is to be rendered active, it is desired to break the connection between the tube socket contacts 1 and 4 afforded by the jumper 185 so as to enable a check to be properly made as to the presence or absence of a jumper as 66', Fig. 18, in the base of the tube as 18' which is to be inserted in the tube socket 9. To this end, the tube socket 9 of each spare unit SU' is equipped with a screw 186, Figs. 7, 7A and 7B, which is fitted into the central opening of the socket 9. As shown in Fig. 7A, the shank of the screw 186 extends downwardly through the opening in the socket 9 and a nut 187 is threaded thereon to clamp the screw 186 in place. Two holes are drilled through the shank of the screw 186, and the jumper 185 connected to the contacts 1 and 4 of the tube socket 9 is passed through one of these openings as shown in Figs. 7A and 7B. Before a tube can be inserted in the socket 9, it is necessary to first remove the screw 186 and this cannot be done without first breaking or removing the jumper 185. This insures that a tube will not be accidentally inserted while the jumper remains whole, and hence there will not be any false indication of the presence of a jumper as 66', Fig. 4, in the base of the tube if such is not actually the case.

It is also necessary to insure continuity of the series circuit which extends through the contacts 161 of the relays 158 in the active secondary units SU, Figs. 4 and 5. The relays as 158 (not shown in Fig. 6) in the spare units SU' are not operated so long as the spare units are not in service. Therefore, in order to insure completion of the series circuit which must be established through the contacts 161 of the relays 158 of the active units SU, the spare units SU' are provided with insulated jumpers 190 for interconnecting the terminals 157 and 162 of these units. The jumpers 190, like the jumpers 185, are passed through holes in the shanks of the screws 186 in the tube sockets 9 of the respective units SU', as shown in Figs. 7A and 7B, and hence it is necessary to break or remove a jumper 190 before a tube can be inserted in the socket of any spare unit SU'.

It is not necessary to provide jumpers to interconnect the terminals 178 and 180 of the spare units SU' inasmuch as these terminals are normally electrically connected through the contacts as 179, Fig. 4, of the relays as 158 in the units SU'. It is manifest, however, that if a relay as 158 is not installed in a spare unit SU' it will be necessary to provide a jumper similar to the jumper 190 to interconnect the terminals 178 and 180 in order to afford continuity of the series circuit extending through the contacts 179 of the relays 158 in the active units SU. This jumper will then be passed through a hole in the shank of the screw 186 in the same manner as in the case of the jumpers 158 and 190 so that it must be removed before putting the spare unit SU into service.

In the embodiment of the invention illustrated in Figs. 3, 4 and 5, the flame-sensing circuit of the master unit MU is arranged differently than the flame-sensing circuits of the secondary control units SU; that is to say, the condenser 37 and resistor 31 of the master unit MU are elec-

trically connected to the cathode return wire 32 by way of a series circuit extending through the contacts 179 of the relays 158 in the secondary units SU, whereas the condensers 31' and resistors 31' of the secondary units SU are connected directly to their cathode return wires 32'. There may be instances in which it is desired to have the flame-sensing circuits of all the control units arranged in an identical manner and yet insure that the main fuel valve 55 is not opened until pilot flames have been established in all of the pilot burners in the system. To this end, and for the purpose of effecting various other improvements, the modification shown in Fig. 8 may be conveniently utilized.

The control apparatus shown in Fig. 8 comprises a relay unit RU which contains certain of the relays and associated devices for controlling operation of the fuel supply and ignition means. Operation of this relay unit RU is in turn governed by the flame-detecting units U, one of which is operatively associated with each pilot burner 50 in the system. The control units U are of uniform construction and each includes an electron tube 192 and a relay 193 having its winding connected in the anode circuit of said tube. The filaments of the tubes 192 are preferably supplied with current by individual filament transformers 194 having their primaries connected across terminals 195 and 196 which are respectively connected to the line wires L2 and L0. The cathodes 197 of the tubes 192 are connected to terminals 198 which are electrically connected to the line wire L1. The anode 199 of each tube 192 is connected by a conductor 200 to one end of the winding of the relay 193, the other end of this winding being connected by the conductor 201 to the terminal 195. It will be understood that although the relay unit RU and flame-detecting units U are represented in Fig. 8 as constituting separate units, they may be conveniently incorporated in the same cabinet to afford a single control unit for the entire burner system.

It will be recalled that the line wire L1 is not immediately potentialized upon closure of the switch S but must await the establishment of an electrical connection with the wire L0 through the medium of the preliminary control apparatus 59. Hence, while closure of the switch S immediately potentializes the wires L0 and L2 for thereby energizing the filament transformers 194 and initiating heating of the cathodes 197, the line potential is not impressed upon the anode circuits of the tubes 192 until the scavenging and other preliminary operations have been performed under control of the apparatus 59. Ordinarily this affords sufficient time for the tubes 192 to be conditioned for operation, but if a longer delay period is desired this can be afforded by an arrangement such as that comprising the thermal switch 73 and relay 76, Fig. 3. It is likewise apparent that the series circuit arrangement of jumpers 66 and 66', Figs. 4 and 5, may be employed to insure that the control apparatus is not conditioned for operation unless tubes of the proper type are installed in all of the active control units U. At the completion of the aforesaid scavenging cycle the line wire L1 assumes the same potential as the line wire L0, whereupon a circuit is established from wire L1 through a conductor 202, a contact blade 203 of a relay 204 included in the relay unit RU, a contact 203a with which the blade 203 cooperates when the relay 204 is deenergized, and thence through an alarm 89 back to the line wire L2. Operation of the alarm 89 thus signifies that the necessary preliminary operations have been performed and that the heater system is ready for operation.

As the line wire L1 becomes potentialized the voltage existing between the wires L1 and L2 is impressed across the cathodes 197 and anodes 199 of the various tubes 192. The control grids 205 of the tubes 192 are respectively connected by conductors 206 to terminals 207 on the control units U, from which terminals the conductors 30 lead to the respective flame-sensing electrodes 17 associated with the pilot burners 50. The sheaths 34 of the conductors 30 are respectively connected to terminals 208 which are electrically connected through the filaments of lamps 209 to the terminals 198 on the units U. Each control unit U has a condenser 210 and a resistor 211 which are electrically connected in parallel across the terminals 207 and 208. Since there is no current flow through the various flame-sensing circuits including the electrodes 17, conductors 30, condensers 210 and resistors 211 prior to the establishment of pilot flames in the burners 50, there is initially no substantial negative bias on the control grids 205 so that the tubes 192 are able to conduct current as soon as the line wire L1 is potentialized. If each tube is in good condition so that it passes current through its anode circuit, then all of the relays 193 in the various control units U become energized, but if any tube is defective so that it is permanently nonconductive, its relay 193 remains in a deenergized condition.

Energization of the relays 193 serves to establish a series circuit through the contacts 212 of these relays for the purpose of conditioning the relay unit RU to initiate operation of the pilot burners 50. Each relay contact 212 is arranged to bridge a pair of terminals 213 and 214 on its control unit U when the relay 193 is energized. The terminal 214 of the last control unit U in the series is connected to the line wire L1, while the terminal 214 of each of the other units U is connected by a conductor 215 to the terminal 213 of the next succeeding unit U in the series. A conductor 216 leads from the terminal 213 of the first unit U to a contact 203b of the relay 204 in the unit RU, from which relay contact the blade 203 is normally disengaged when the relay 204 is deenergized. A push button 217 is arranged to bridge a pair of spaced contacts 218, one of which is connected to the conductor 216 and the other to a conductor 219 leading to the winding of the pilot fuel valve solenoid 56. Assuming that all of the tubes 192 are conducting current so that all of the relays 193 are energized to maintain their contacts 212 closed, an electrical path is established from the line wire L1 through the relay contacts 212 in series to the conductor 216. However, if any of the tubes 192 is defective so that its relay 193 remains deenergized, the conductor 216 remains disconnected from the line wire L1.

Assuming that all of the tubes 192 are conducting current, operation of the pilot burners 50 is initiated by manually closing the switch 217 whereby a circuit is completed through the winding of the solenoid 56 for energizing this solenoid and opening the pilot fuel valve 54. Closure of the switch 217 also causes a circuit to be extended through the conductor 219, a blade 220 of a relay 221 included in the unit RU, a contact 220a which the blade 220 normally engages and

a conductor 222 to the distributor motor 175 and the primary of the ignition transformer 135. The motor 175 thereupon drives the wiper 173 of the distributor 170 rotatively for applying the high potential of the transformer secondary successively to the spark plugs 136 of the pilot burners 50. Still another circuit is established upon closure of the switch 217, this circuit extending through the conductor 219 and the winding of the relay 204 to the line wire L2. Relay 204 thereupon energizes and shifts its contact blade 203 into engagement with the contact 203b, at the same time closing another relay contact 223. As an incident to the energization of the relay 204 circuit to the alarm 89 is broken and this alarm ceases operating. If desired the alarm 89 can be arranged in the manner shown in Fig. 3 so that it commences to operate as soon as the switch S is closed rather than at the end of the preliminary scavenging cycle. With either arrangement, if the alarm 89 continues to operate when the switch as 217 is closed, this is indicative that there is a defective tube in one of the control units U.

As the fuel admitted to each pilot burner 50 is ignited there is created a flow of rectified current through the condenser 210 in the flame-sensing circuit associated with such pilot burner, thereby applying a negative bias to the control grid 205 of the associated tube 192. This tube thereupon ceases to conduct current and the relay 193 in the anode circuit of the tube is deenergized to open the relay contact 212. Such opening of the relay contacts 212, however, has no effect upon the pilot burners because when the relay 204 became energized in the manner explained hereinabove it closed a circuit from the line wire L1 through the conductor 202 and relay contact 203b to the conductor 216, thus affording a self-locking arrangement for the relay 204 so long as the switch 217 is maintained closed. Hence the pilot valve solenoid 56 and the ignition means remain in operation for establishing pilot flames in the burners 50. The flow of rectified current through each flame-sensing circuit is of a relatively small value so that the lamps 209 are not illuminated by the passage of such current through their filaments.

Each of the relays 193 has a contact 225 which is normally closed when the relay is deenergized, this contact bridging a pair of terminals 226 and 227 on the control unit U. The terminal 227 of the last unit U in the series is connected directly to the line wire L1 while the terminal 227 on each of the other control units U is connected by a conductor 228 to the terminal 226 on the next succeeding unit U. A conductor 229 leads from the terminal 226 on the first control unit U in the series to a terminal of the contact 223 of the relay 204. Thus, when pilot flames have been established in all of the burners 50 to bring about deenergization of all of the relays 193, a series circuit is completed from the line wire L1 through the relay contacts 225 to the conductor 229, thence through the contact 223 of relay 204 to a conductor 230 from which a conductor 231 leads to the winding of the relay 221, the circuit then being completed through the winding of the relay 221 to the line wire L2. Relay 221 energizes to disengage the contact blade 220 from the contact 220a and shift this blade into engagement with another contact 220b that is connected by a conductor 232 to the conductor 230. As a result of this the ignition means comprising the distributor motor 175 and ignition transformer 135 is disabled and a holding circuit is completed from the conductor 230 through the relay contact 220b and conductor 219 to the winding of the relay 204. The relays 221 and 204 are thus held energized through a common holding circuit which passes through the contacts 220b and 223 of these relays, respectively, this holding circuit continuing so long as all of the relays 193 in the control units U remain deenergized. Concurrently with the establishment of the aforesaid holding circuit a lamp 142 connected between the conductor 230 and the line wire L2 becomes illuminated to signal the operator that he may release the push button 217, the pilot burners 50 then being in full operation.

To initiate operation of the main burners a push button 233 is depressed to close circuit from the conductor 230 to another conductor 234 leading to the winding of the main fuel valve solenoid 57, causing this solenoid to energize and open the main fuel valve 55. Closure of the switch 233 also extends a circuit through the conductor 234 and winding of a relay 235 to the line wire L2. Relay 235 has a normally open contact 236 connected in parallel with the switch 233, and upon energization of this relay the contact 236 closes and establishes a holding circuit for the relay 235 and solenoid 57 so that the push button 233 may be released. A lamp 146 connected between the conductor 234 and line wire L2 then flashes on to indicate that the main burners are in operation.

In the event there is a flame failure at any of the burners the tube 192 in the control unit U associated with such burner becomes conductive and energizes its relay 193, thereby opening the relay contact 225 and breaking the series path from the line wire L1 to the conductor 216. In this manner the holding circuits of the relays 204, 221 and 235 are broken and these relays deenergize, thereby causing the fuel valve solenoids 56 and 57 to deenergize and close the fuel valves 54 and 55. Moreover, the lamps 142 and 146 are extinguished and the alarm 89 commences to operate in the usual manner.

Similarly, the occurrence of any of the other hazardous conditions against which the apparatus is designed to safeguard, such as grounding of a flame-sensing electrode 17, establishment of artificial leakage paths across the flame gaps or insulation failure, will serve to bring about a safe operation of the system in the manner explained hereinabove with reference to other embodiments of the invention. Likewise, if any of the sheaths 34 becomes grounded, the corresponding lamp 209 lights to indicate the fault and the system fails safely.

It will be understood that the apparatus illustrated in Fig. 8 can be arranged to accommodate spare control units in a manner similar to that explained hereinabove in connection with Fig. 6.

Summary

From the foregoing description it will be apparent that we have provided 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 it-

self 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 electrode or a part of the burner structure, or as a result of 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 occurrence of any of the undesirable contingencies mentioned above, and preferably the arrangement is such that an electron tube is rendered nonconductive when a flame is present in the burner and 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 the circuits are so arranged that the charge on the condenser is built up during those half-cycles of the alternating current in which the electron tube is inoperative, that is to say, during the inverse half-cycles, and this charge becomes effective during the intervening half-cycles, that is to say, the forward half-cycles, to render the tube nonconductive. So long as the tube is maintained in a continuously nonconductive 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 conductive during forward half-cycles of the alternating current. 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.

One of the advantages incident to the leakage detection feature of the present invention consists in that there is no need to recycle the burner system in order to produce a safe reaction of the control apparatus in the event a leakage path develops in the region of the flame while the burner system is in operation. Even in case of the most critical values of leakage resistance the control apparatus will permit fuel to be supplied to the system, if at all, only so long as the flame does not fail. In some of the prior fuel burner systems and control apparatus therefor it has been possible to prevent the admission of fuel to a burner whenever a leakage resistance having the same ohmic value as a normal flame exists between the flame-sensing electrodes before operation of the system commences. However, if such leakage resistance develops while a flame is present, then a subsequent accidental extinction of the flame is without effect upon the control apparatus, and fuel continues to be supplied until a recycling of the system is brought about by external means such as a room thermostat. Our invention, on the oher hand, effects an immediate shut-down of the system upon flame failure whether or not the flame electrodes are bridged by leakage resistances.

The preferred form of the apparatus is so arranged that each electron tube is maintained continuously nonconductive so long as there is a safe condition in its burner, which is to say during the greater part of the time, thereby prolonging its life. However, since there is always the danger that the tube may fail internally and thereby become permanently nonconductive irrespective of conditions in the burner, it is desirable to have some means of automatically checking the tube to insure that it is capable of conducting current in response to unsafe conditions in the burner if the need so to do should arise. A tube is more likely to fail internally while it is in a conductive state than when it is nonconductive. Such failure of the tube while it is in a conductive state is not immediately hazardous because the tube by becoming conductive will have already effected a shut-down of the burner system, so that if it fails in the serise of becoming permanently nonconductive at such time no immediate harm will be done. However, there is a danger that when the system is again started in operation under manual control the tube, being incapable of conducting current at any time, may give a false indication that the burner and control apparatus are operating safely unless precautions are taken to prevent the burner from operating if the tube is not capable of passing current when required to do so.

In view of the difficulty just described, we have provided an automatic tube checking means for testing the conductivity of each and every electron tube in the control apparatus as a condition precedent to initiating operation of the burner or burners, and unless each tube is initially in a conductive state (as it should be since there are no flames in the burners) no fuel will be supplied to the system. One of the advantages of an arrangement such as has just been described is that the tubes may, with safety, be adapted to remain nonconductive during the greater portion of the time, becoming conductive only in comparatively rare instances when an abnormal condition occurs, and in this way the life of the tube is greatly prolonged. There is also the advantage that if a tube should fail in such a manner that it becomes permanently conductive, the apparatus immediately reacts as though to an unsafe condition.

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 many parts such as relays, fuel valves and transformers is avoided by providing a single master control unit to control a common fuel supply and ignition 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 and ignition means, as illustrated in Figs. 2, 4 and 5. If desired, the control units associated with the various burners may be of uniform construction, as shown in Fig. 8, to facilitate manufacture thereof. Where spare units are to be installed, as shown in Fig. 6, and it is necessary to establish temporary electrical connections through these spare units, means have been provided to insure that such temporary connections will be destroyed before any spare unit can be put into active service, as explained hereinabove in connection with Figs. 7A and 7B.

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

We claim:

1. In an apparatus adapted to be operated from a source of electric current for controlling the operation of associated equipment which may include a plurality of operating units, at least one control unit each provided with an electron tube arranged to be operated in accordance with predetermined conditions in an associated operating unit, at least one spare control unit each adapted to utilize an electron tube operatively associated with an additional operating unit when needed, each of said control units and spare units also including a relay arranged to be operated in response to the conduction of current by the tube, if any, embodied in such control unit, means rendered effective when the relays in all of said control units are concurrently operative to condition the equipment for operation, thereby affording a check on the conductivity of each tube as a condition precedent to operation of said equipment, special means associated with each spare control unit to enable said equipment to be conditioned for operation in the absence of a tube in such spare control unit notwithstanding that the relay in such spare control unit is not operated, and means to compel the disabling of the special means for a particular spare unit before a tube can be installed in such control unit, whereby the conductivity of a tube installed in any spare control unit may be checked in the same manner as in the case of the tubes in the other of said control units.

2. A control apparatus adapted to utilize a plurality of electron tubes for controlling the operation of associated equipment, each of said tubes normally being provided with two electrically interconnected prongs, the combination therewith of a plurality of sockets each having individual contact means for receiving the normally interconnected prongs of a tube, said plurality of sockets including at least one spare socket each of which may receive a tube upon being called into service, connecting means constituted and arranged to provide a circuit extending in series through the contact means of said tube sockets, said circuit being completed when tubes having interconnected prongs as aforesaid are received in all of said plurality of sockets, an individual jumper for each spare socket to electrically interconnect the contact means thereof that are adapted to receive the interconnected prongs of a tube, whereby said series circuit may be completed notwithstanding that no tube is received in any of the spare sockets, means rendered effective only when said circuit is completed for enabling operation of said equipment, and means associated with each spare socket for compelling destruction of the jumper connection between the contact means of such socket before a tube can be received therein, whereby the apparatus is able to check each additional tube as to the electrical connections of its prongs in the same manner as in the case of the original tubes.

3. In a multiple heater system having a plurality of fuel burners each equipped with a device for sensing the presence of a flame in its burner, the combination of a plurality of electron tubes, means affording a corresponding plurality of input circuits one for each of said tubes and each controlled by a respective sensing device, a plurality of relays, means affording a plurality of output circuits one for each of said tubes and each including the winding of a corresponding relay, means for starting all of said burners in operation, each of said tubes except one responding to the sensing of a flame by the device in its input circuit to operate the relay in its output circuit, said one tube operating its relay in response to the sensing of a flame by the device in its input circuit only when all of the other relays have been operated whereby operation of the one relay is delayed until flames have been established in all of said burners, and means under control of said one relay for maintaining said burners in operation after said starting means is disabled so long as said one relay remains operative, each of said other relays having a contact which is closed when its relay is operated, and said input circuit for said one tube extending through said relay contacts in series.

4. In a control system, a plurality of sensing devices for sensing the presence of a desired operating condition, a plurality of electron tubes, means affording a corresponding plurality of input circuits one for each of said tubes and each controlled by a respective sensing device, a main control relay and a plurality of other relays, means affording a plurality of output circuits one for each of said tubes and each including the winding of a corresponding relay, each of said tubes except the one associated with said main control relay responding to the sensing of the desired operating condition by the sensing device in its input circuit to operate the relay in its output circuit, each of said other relays having a contact which is closed when its relay is operated and said input circuit for said one tube extending through said relay contacts in series, whereby said one tube operates said main control

relay in response to the sensing of the desired operating condition by the sensing device in its input circuit only when all of the other relays have been operated and operation of said main control relay is delayed until the desired operating condition has been sensed by the sensing devices associated with said one tube as well as with all of the other tubes.

5. In a safety control system, a burner, means for supplying fuel to said burner, an electrically operated control device for governing said fuel supply means and having a first condition which it assumes when electrically energized to supply fuel to said burner and having a second condition which it assumes when it is not electrically energized to prevent supply of fuel to said burner, a control relay having an operating coil and normally closed contacts, an energizing circuit for said electrically operated control device including said relay contacts, a flame electrode normally insulated from said burner and disposed in the path of a flame propagated from said burner, an electronic discharge device having an anode, a cathode and a control grid, a source of alternating current, means connecting one pole of said source through said relay coil to said anode, means connecting the other pole of said source to said cathode and said control grid to normally render said discharge device conductive during those cycles of the alternating current when said anode is positive with relation to said cathode and thereby pass energizing current to said relay to operate the same and thereby open said energizing circuit, means affording an electrical path from said burner to the side of said alternating current source which is connected to said anode, a conductor connecting said flame electrode to said control grid, means affording a capacitance connected on one side to said control grid and on the other side to said cathode, and a leakage resistance connected in parallel with said capacitance between said control grid and said cathode.

6. In a safety control system, a burner, means for supplying fuel to said burner, an electrically operated control device for governing said fuel supply means and having a first condition which it assumes when electrically energized to supply fuel to said burner and having a second condition which it assumes when it is not electrically energized to prevent supply of fuel to said burner, a control relay having an operating coil and normally closed contacts, an energizing circuit for said electrically operated control device including said relay contacts, a flame electrode normally insulated from said burner and disposed in the path of a flame propagated from said burner, an electronic discharge device having an anode, a cathode and a control grid, a source of alternating current having first and second poles, means connecting the first pole of said source through said relay coil to said anode, means connecting the second pole of said source to said cathode and said control grid to normally render said discharge device conductive during those cycles of the alternating current when said anode is positive with relation to said cathode and thereby pass energizing current to said relay to operate the same and thereby open said energizing circuit, means affording a bi-laterally conductive electrical path from said burner to said first pole, a conductor connecting said flame electrode to said control grid, means affording a capacitance connected on one side to said control grid and on the other side to said cathode, and a leakage resistance connected in parallel with said capacitance between said control grid and said cathode.

7. In a safety control system, a burner, means for supplying fuel to said burner, an electrically operated control device for governing said fuel supply means and having a first condition which it assumes when electrically energized to supply fuel to said burner and having a second condition which it assumes when it is not electrically energized to prevent supply of fuel to said burner, a control relay having an operating coil and normally closed contacts, an energizing circuit for said electrically operated control device including said relay contacts, a flame electrode normally insulated from said burner and disposed in the path of a flame propagated from said burner, an electronic discharge device having an anode, a cathode and a control grid, a source of alternating current, means connecting one pole of said source through said relay coil to said anode, means connecting the other pole of said source to said cathode and said control grid to normally render said discharge device conductive during those cycles of the alternating current when said anode is positive with relation to said cathode and thereby pass energizing current to said relay to operate the same and thereby open said energizing circuit, means affording a bi-laterally conductive electrical path from said burner to the side of said alternating current source which is connected to said anode, a conductor connecting said flame electrode to said control grid, means including a sheath surrounding at least a portion of said conductor and affording a capacitance connected on one side to said control grid and on the other side to said cathode, a leakage resistance connected in parallel with said capacitance between said control grid and said cathode, a protective conduit surrounding said sheath in insulated relation thereto, and means affording a bi-laterally conductive electrical path from said conduit to the side of said alternating current source which is connected to said anode.

8. In a safety control system, a burner, means for supplying fuel to said burner, an electrically operated control device for governing said fuel supply means and having a first condition which it assumes when electrically energized to supply fuel to said burner and having a second condition which it assumes when it is not electrically energized to prevent supply of fuel to said burner, a control relay having an operating coil and normally closed contacts, an energizing circuit for said electrically operated control device including said relay contacts, a flame electrode normally insulated from said burner and disposed in the path of a flame propagated from said burner, an electronic discharge device having an anode, a cathode and a control grid, a source of alternating current having first and second poles, means connecting the first pole of said source through said relay coil to said anode, means connecting the other pole of said source to said cathode and said control grid to normally render said discharge device conductive during those cycles of the alternating current when said anode is positive with relation to said cathode and thereby pass energizing current to said relay to operate the same and thereby open said energizing circuit, means affording a ground connection from said first pole, means affording a ground connection for said burner, a conductor connecting said flame electrode to said control grid, means affording a capacitance connected

on one side to said control grid and on the other side to said cathode, and a leakage resistance connected in parallel with said capacitance between said control grid and said cathode.

9. In a safety control system, a burner, means for supplying fuel to said burner, an electrically operated control device for governing said fuel supply means and having a first condition which it assumes when elecrically energized to supply fuel to said burner and having a second condition which it assumes when it is not electrically energized to prevent supply of fuel to said burner, a control relay having an operating coil and normally closed contacts, an energizing circuit for said electrically operated control device including said relay contacts, a flame electrode normally insulated from said burner and disposed in the path of a flame propagated from said burner, an electronic discharge device having an anode, a cathode and a control grid, a source of alternating current having first and second poles, means connecting the first pole of said source through said relay coil to said anode, means connecting the other pole of said source to said cathode and said control grid to normally render said discharge device conductive during those cycles of the alternating current when said anode is positive with relation to said cathode and thereby pass energizing current to said relay to operate the same and thereby open said energizing circuit, means affording a ground connection from said first pole, means affording a ground connection for said burner, a conductor connecting said flame electrode to said control grid, means including a sheath surrounding at least a portion of said conductor and affording a capacitance connected on one side to said control grid and on the other side to said cathode, a leakage resistance connected in parallel with said capacitance between said control grid and said cathode, a protective conduit surrounding said sheath in insulated relation thereto, and means affording a ground connection for said conduit.

10. In a safety control system, a burner, means for supplying fuel to said burner including a normally closed valve, a solenoid operable when energized to open said valve, a source of alternating current having first and second poles, a control relay having normally closed contacts, an energizing circuit for said solenoid including said normally closed relay contacts, a flame electrode normally insulated from said burner and disposed in the path of a flame propagated from said burner, an electronic discharge device having an anode, a cathode and a control grid, means connecting the first pole of said source through said relay to said anode, means connecting the other pole of said source to said cathode and said control grid to normally render said discharge device conductive during those cycles of the alternating current when said anode is positive with relation to said cathode and thereby pass energizing current to said relay to operate the same and thereby open said energizing circuit, means affording a ground connection from said first pole, means affording a ground connection for said burner, a conductor connecting said flame electrode to said control grid, means including a sheath surrounding at least a portion of said conductor and affording a capacitance connected on one side to said control grid and on the other side to said cathode, a leakage resistance connected in parallel with said capacitance between said control grid and said cathode, a protective conduit surrounding said sheath in insulated relation thereto, and means affording a ground connection for said conduit.

11. In a safety control system, a plurality of burners, means for supplying fuel to all of said burners, an electrically operated control device for governing said fuel supply means and having a first condition which it assumes when electrically energized to supply fuel to said burners and having a second condition which it assumes when it is not electrically energized to prevent supply of fuel to said burners, a control relay having an operating coil and normally closed relay contacts, an energizing circuit for said electrically operated device including said contacts, a plurality of flame electrodes allocated respectively to said burners and disposed in insulated relation to their respective burners and in positions in the paths of the respective flames which may be propagated from their burners, a plurality of electronic discharge devices allocated one to each of the respective burners and each having an anode, a cathode and a control electrode, a source of alternating current, means electrically connecting one side of said source through said relay coil and then in parallel to the anodes of the respective discharge devices, means affording a plurality of branch leads in parallel from the other side of said source and connected to the cathodes and grids of the respective electron discharge devices to normally render such devices conductive during those cycles of the alternating current when the anodes are positive with relation to the cathodes of such devices to thereby pass energizing current to said relay coil to operate the same and open said energizing circuit, means affording a bi-laterally conductive electrical path from all of said burners to the side of said alternating current source that is connected to said anodes, a plurality of conductors one allocated to each flame electrode and each extended from its flame electrode to the control grid of the related electron discharge device, individual means associated with each such conductor and affording a capacitance connected on opposite sides to the control grid and cathode respectively of the related electron discharge device, and a plurality of leakage resistors one of which is connected in parallel across each such capacitance.

12. In a safety control system utilizing a plurality of electron tubes and adapted to be operated from a source of electric current for controlling the operation of associated equipment that includes a plurality of operating units, said tubes each having a base and an envelope enclosing operative elements and having a plurality of prongs on said base at least a pair of which are electrically independent of said operative elements and at least certain others of which are electrically associated with the respective operative elements of the tubes, a special conductor included on said base of each tube electrically independent of said other prongs and said operative elements of the tube and electrically connecting said pair of prongs of the tube, a plurality of sockets, one for each of said tubes, and each socket being adapted to receive said plurality of prongs of the related one of said tubes and including a pair of special contacts for receiving the respective prongs of said pair of prongs to be thereby electrically interconnected by said special conductor of the tube mounted thereon and also including other contacts for receiving the respective other prongs of the tube, means electrically connecting one of said pair of contacts to one pole of said source of current, means

affording an enabling circuit leading from the opposite poles of said source and through said pairs of contacts of the several sockets and the special conductors of the tubes mounted in such sockets, said apparatus being conditioned to enable operation of said equipment only when the tubes mounted in all of said sockets include special conductors as aforesaid for potentializing said enabling circuit, and whereby the substitution of a tube which does not include such a special conductor prevents said equipment from operating.

13. In a safety control system utilizing an electron tube and adapted to be operated from a source of electric current for controlling the operation of associated equipment, said tube having a base and an envelope enclosing operative elements and having a plurality of prongs on said base at least a pair of which are electrically independent of said operative elements and at least certain others of which are electrically associated with the respective operative elements of the tube, a special conductor included on said base electrically independent of said other prongs and said operative elements and electrically connecting said pair of prongs, a socket for receiving said plurality of prongs and including a pair of special contacts for receiving the respective prongs of said pair of prongs to be thereby electrically interconnected by said special conductor of the tube and including other contacts for receiving the respective other prongs of the tube, means electrically connecting one of said pair of contacts to one pole of said source of current, means affording an enabling circuit leading from the other pole of said source to the other one of said pair of contacts, said apparatus being conditioned to enable operation of said equipment only when a tube mounted in said socket includes a special conductor as aforesaid for potentializing said enabling circuit, and whereby the substitution of a tube which does not include such a special conductor prevents said equipment from operating.

14. In a safety burner control system, a burner, means for supplying fuel to said burner, an electrically operated control device for governing said fuel supply means and having a first condition which it assumes when electrically energized to supply fuel to said burner and having a second condition which it assumes when it is not electrically energized to prevent supply of fuel to said burner, a flame electrode normally insulated from said burner and disposed in the path of a flame propagated from said burner, an electronic discharge tube having an anode, a cathode and a control grid, a source of alternating current, means connecting one pole of said source through said primary relay coil to said anode, means connecting the other pole of said source to said cathode and said control grid and including a grid resistor and operable to normally render said tube conductive during those cycles of the alternating current when said anode is positive with relation to said cathode and thereby pass energizing current to said relay to operate the same, means affording an electrical path from said burner to the side of said alternating current source which is connected to said anode, a conductor connecting said flame electrode to said control grid, means affording a capacitance connected on one side to said control grid and on the other side to said cathode, and said grid resistor constituting a leakage resistance connected in parallel with said capacitance between said control grid and said cathode, to thereby render said tube non-conductive when a flame is propagated from said burner into contact with said electrode and to render said tube conductive when such a flame is absent or when said electrode becomes grounded or becomes otherwise bilaterally connected to said burner, a governing relay having normally open contact means, an energizing circuit for said electrically operable control device including said normally open contact means of said governing relay, said primary relay having a pair of normally closed contacts and a pair of normally open contacts, an energizing circuit for said governing relay including said normally open pair of contacts of said primary relay whereby initial energization of said governing relay may take place only during energization of said primary relay, and means affording a holding circuit for said governing relay including said normally open contact means of said governing relay and the pair of normally closed contacts of said primary relay, whereby initial supply of fuel to said burner is rendered dependent on conductivity of said tube while continued supply of fuel after combustion is rendered dependent upon maintenance of a non-conductive condition in said tube.

15. In a safety burner control system, a plurality of burners, a common means for supplying fuel to all of said burners, an electrically operated control device for governing said fuel supply means and having a first condition which it assumes when electrically energized to supply fuel to said burners and having a second condition which it assumes when it is not electrically energized to prevent supply of fuel to said burners, a plurality of flame electrodes allocated one to each of said burners and normally insulated from such burners and each disposed in the path of a flame propagated from its respective burner, a plurality of electronic discharge tubes allocated one to each of said burners and each having an anode, a cathode and a control grid, a source of alternating current, a plurality of primary relays allocated one to each of said burners, means connecting one pole of said source through each of said primary relay coils to the anode of the related tube, means normally connecting the other pole of said source to the cathodes of the several tubes to normally render each of the tubes conductive during those cycles of the alternating current when the anodes of such tubes are positive with relation to the respective cathodes thereof and thereby pass energizing current to the associated primary relays to operate the same, means affording electrical paths from the respective burners to the side of said alternating current source which is connected to said anodes, an individual conductor for each flame electrode connecting such flame electrode to the control grid of the related tube, a governing relay having normally open contact means, an energizing circuit for said electrically operable control device including the contact means of said governing relay, each of said primary relays having a pair of normally closed contacts, and a pair of normally open contacts, an energizing circuit for said governing relay including the normally open pairs of contacts of all of said primary relays in series whereby initial energization of said governing relay may take place only during energization of all of said primary relays, and means affording a holding circuit for said governing relay including normally open contact means of said governing relay and the pair of normally closed contacts of one of said primary relays in series,

means affording an individual capacitance for each of the tubes related to the other primary relays and connected on one side to the control grid of its tube and on the other side to said cathode of its tube, an individual leakage resistance for each of the tubes related to said other primary relays and each arranged in parallel with the capacitance of its tube and connected between the control grid and the cathode of its tube, to thereby render the related tube non-conductive when a flame is propagated from the related burner into contact with the related electrode and to render the related tube conductive when such a flame is absent at the related burner or when the related electrode becomes grounded or becomes otherwise bilaterally connected to its burner, circuit means connected at its opposite ends to the cathode and grid respectively of the tube that associated with said one primary relay and including a resistance and a capacitance in parallel and the normally closed contacts of all of the other primary relays in series.

16. In a safety burner control system, a plurality of burners, a common means for supplying fuel to all of said burners, an electrically operated control device for governing said fuel supply means and having a first condition which it assumes when electrically energized to supply fuel to said burners and having a second condition which it assumes when it is not electrically energized to prevent supply of fuel to said burners, a plurality of flame electrodes allocated one to each of said burners and normally insulated from such burners and each disposed in the path of a flame propagated from its respective burner, a plurality of electronic discharge tubes allocated one to each of said burners and each having an anode, a cathode and a control grid, a source of alternating current, a plurality of primary relays allocated one to each of said burners, means connecting one pole of said source through each of said primary relay coils in parallel to the anode of the related tube, means connecting the other pole of said source to the cathodes and the control grids of the several tubes to normally render each of the tubes conductive during those cycles of the alternating current when the anodes of such tubes are positive with relation to the respective cathodes thereof and thereby pass energizing current to the associated primary relays to operate the same, means affording electrical paths from the respective burners to the side of said alternating current source which is connected to said anodes, an individual conductor for each flame electrode connecting such flame electrode to the control grid of the related tube, means affording an individual capacitance for each of said tubes connected on one side to the control grid of its tube and on the other side to said cathode of its tube, an individual leakage resistance for each of said tubes and each arranged in parallel with the capacitance of its tube and connected between the control grid and the cathode of its tube, to thereby render the related tube non-conductive when a flame is propagated from the related burner into contact with the related electrode and to render the related tube conductive when such a flame is absent at the related burner or when the related electrode becomes grounded or becomes otherwise bilaterally connected to its burner, a governing relay having normally open contact means, an energizing circuit for said electrically operable control device including the contact means of said governing relay, each of said primary relays having a pair of normally closed contacts and a pair of normally open contacts, an energizing circuit for said governing relay including the normally open pairs of contacts of all of said primary relays in series whereby initial energization of said governing relay may take place only during energization of all of said primary relays, and means affording a holding circuit for said governing relay including normally open contact means of said governing relay and the pairs of normally closed contacts of all of said primary relays in series whereby initial supply of fuel to said burners is rendered dependent on conductivity of all of said tubes while continued supply of fuel after establishment of combustion at all of said burners is rendered dependent upon maintenance of a non-conductive condition in all of said tubes.

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