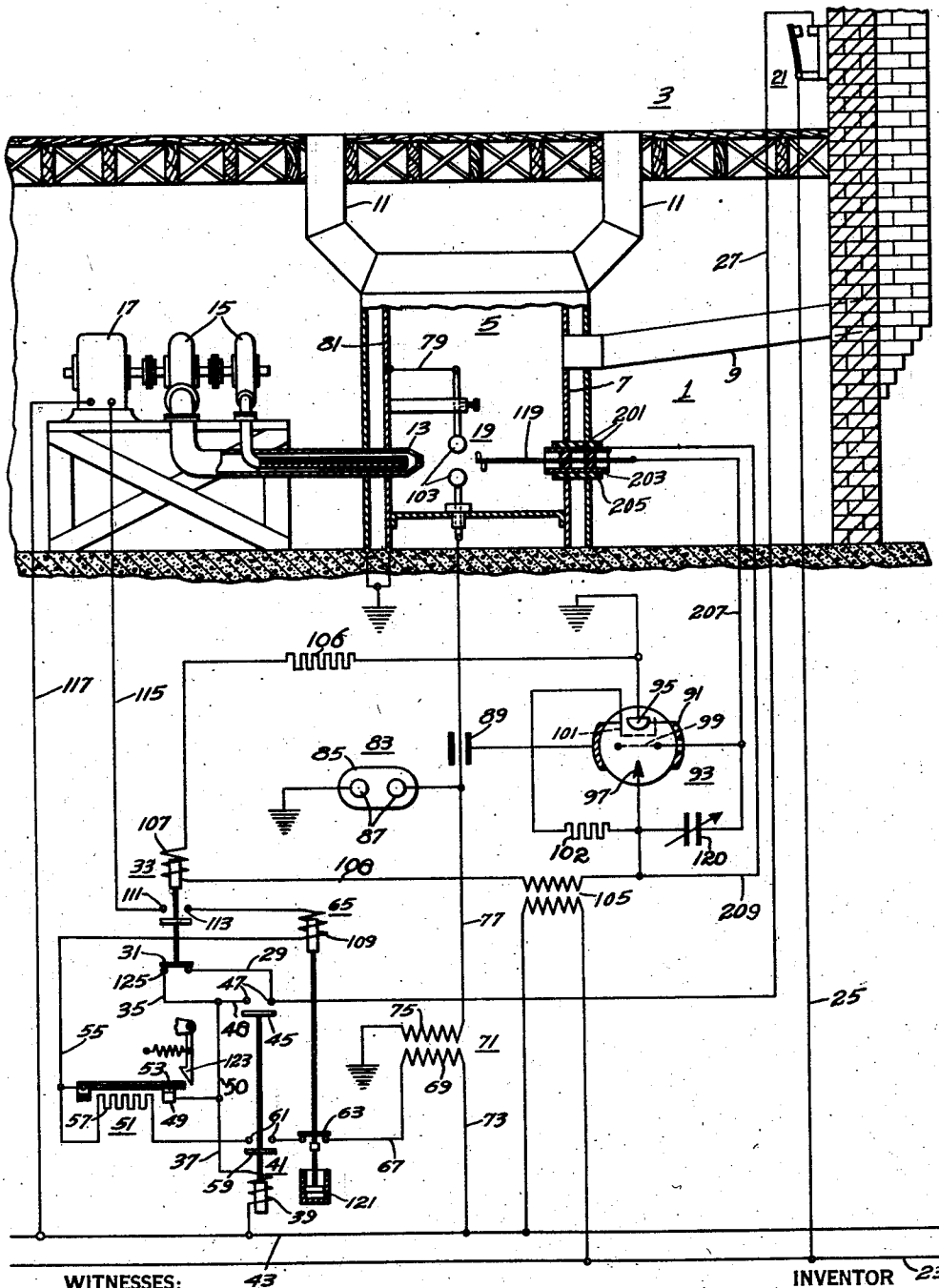
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CONTROL APPARATUS

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CONTROL APPARATUS

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My invention relates to control apparatus and has particular relation to apparatus for controlling combustion.

A combustion control system, particularly where a fluid fuel such as oil or gas is utilized is customarily automatic in operation and incorporates a number of safety features. The fuel is supplied by the operation of a motor-driven pump and when the temperature of the region to be heated is above a predetermined value, the pump motor is deenergized. When the temperature of the region to be heated falls below the value, an electric spark whereby the fuel is to be ignited is first energized. Before the fuel is turned on, the spark is tested to determine whether or not it is capable of igniting fuel. In accordance with the teaching of the prior art of which I am aware, this is accomplished by providing an element responsive to the high frequency field produced by the spark. When a spark of the proper character for igniting the fuel is produced, the element responds to the presence of the high-frequency field and acts to turn on the fuel. The fuel now flows between the spark terminals and is ignited. The spark testing process is generally designated as ignition check.

If the fuel remains ignited, a second element is provided which responds to the presence of the flame to maintain the supply of fuel as long as the flame continues to burn. At the same time, the ignition is generally turned off by the operation of the latter element. If the flame should, during the operation of the burner, be extinguished for one reason or another, the latter element would operate to turn off the fuel. The test of the presence or absence of a flame is designated in the art as flame check.

In accordance with the teachings of the prior art of which I am aware, the element responsive to the spark is, in general, a glow tube energized by the electromagnetic field produced by the spark. The second element which is responsive to the flame is moreover a grid controlled gaseous electric discharge device, the control potential of which is varied by the conductive properties of the flame. In utilizing apparatus incorporating the latter discharge device, another element is necessary, since the soot which is deposited in the region of the flame has a tendency to establish connections between the control electrode and the other electrodes of the discharge device. In accordance with the teachings of the prior art of which I am aware, still another discharge device is provided for preventing the operation of the fuel burner on the occurrence of a soot leakage path in certain critical regions of the fuel burner fire box. The test to detect the presence or absence of leakage is commonly designated as terminal-leakage check.

I have found that the system incorporating the three discharge devices is highly complicated, and by reason of its complexity, uncertainties in its operation are introduced.

I have also found that the glow discharge device that is utilized to turn on the fuel on the ignition of the spark often responds to sparks which are of improper character to ignite the fuel. At times the electrodes of the spark gap become separated or coated with insulating material. When this occurs, the spark is comparatively long and unsatisfactory for ignition purposes. On the other hand, the high frequency field arising from the long spark is often effective in energizing the glow discharge device and it operates to turn on the fuel when the spark is incapable of igniting it.

It is, accordingly, an object of my invention to provide a combustion control system of simplified structure.

Another object of my invention is to provide a combustion control system in which the ignition check, the flame check, and the terminal leakage check, shall be carried out by utilizing a single electric discharge device.

A further object of my invention is to provide a combustion control system in which the fuel shall, under no circumstances, be turned on unless the igniting spark is of the proper quality for ignition.

More concisely stated, it is an object of my invention to provide a system for automatically operating and controlling a fluid fuel burner that shall be of highly simplified structure and at the same time shall operate with the utmost safety.

According to my invention, I provide a system incorporating a discharge device having a control electrode and a plurality of principal electrodes and a gaseous medium. The discharge device is coupled to the supply circuit for the ignition spark gap in such manner that the high frequency field produced by a spark is impressed between the electrodes of the discharge device. The field thus produces ionization of the gas and a discharge current between the principal electrodes. The discharge current transmitted between the principal electrodes energizes the fuel supply motor and the fuel thus supplied is ignited by the spark. The control electrode of the discharge device is coupled to the region of the combustion by a suitable flame electrode, and when the flame is ignited, the effect of its conductivity

on the control electrode potential is to maintain the discharge device energized. It is to be noted, that, in addition, the discharge device is maintained energized by reason of the effect of the ignition spark. After the flame has been energized for a short interval of time, the ignition spark is deenergized, so that if the flame is now extinguished, the discharge device will be deenergized and the fuel supply will be turned off.

In addition to being turned off in response to the presence or absence of a flame, the fuel supply is also turned off when the region to be heated rises above a predetermined temperature. In such a case, the flame is extinguished by reason of the turning off of the fuel and the discharge device is also deenergized. However, if the flame electrode should be accidentally short circuited to ground while the flame is burning, as it might be by breaking, the discharge device will remain energized in spite of the fact that the fuel is later turned off. A device is provided which is responsive to the energized discharge device to prevent the reignition of the igniting spark in this case.

The flame electrode is of such structure that leakage by reason of soot deposit cannot occur between ground and the flame electrode without first occurring between an insulated collar enclosing the flame electrode and either ground or the flame electrode. The collar is connected to the cathode so that if the leakage in either case occurs, the discharge device is deenergized.

To prevent the discharge device from responding when the ignition spark is not of the proper length, an auxiliary spark gap is provided. The latter is shielded from air currents and does not produce an intense high frequency electromagnetic field. It is normally deenergized but is energized when the igniting spark gap is not of the proper length and prevents the ignition spark from being energized.

The novel features that I consider characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and its method of operation, together with additional objects and advantages thereof, will best be understood from the following description of a specific embodiment when read in connection with the accompanying drawing, in which the single figure is a diagrammatic view showing an embodiment of my invention.

In the drawing, a section of the cellar 1 of a house and a portion of one of the rooms 3 to be heated is shown as symbolical of any general arrangement of a combustion system according to my invention. In the cellar 1, the usual furnace 5 is provided. The furnace comprises a fire box 7 in which the combustion takes place and from which the products of combustion are conducted by a suitable tube 9. The air heated by the furnace is conducted to the room 3 to be heated through suitable tubes 11. The fuel to be burned and the necessary air is projected into the fire box 7 through a jet 13 by the operation of a pump 15 of any convenient structure which is operated by a suitable motor 17. In the path of the fuel emitted by the jet 13 from the pump, a spark gap 19 for igniting the fuel is provided.

My system is shown in the drawing in the condition in which it would be when no fire is burning in the box 7. The igniting operation is started by the closing of the room thermostat 21 when the temperature in the room 3 falls below a predetermined value. In such a case, a circuit is closed which extends from a bus 23 of an alternating current supply line through a conductor 25, the room thermostat 21, a conductor 27, a conductor 29, the normally closed lower movable contactor 31 of a first relay 33, a conductor 35, a conductor 5, a conductor 37, the exciting coil 39 of a second relay 41 to the other bus 43 of the alternating current supply line.

The second relay is now operated and closes a circuit which extends from the bus bar 23 through the conductor 25, the room thermostat 21, the conductor 27, an upper movable contactor 45 of the relay 41 which is now engaged with a plurality of corresponding fixed contacts 47, the conductor 48, the conductor 50, the fixed contact 49 of a thermal switch 51, the movable contact 53 of the thermal switch, a conductor 55, the heater 57 of the thermal switch, the lower movable contactor 59 of the relay 41 which is now engaged with a plurality of corresponding fixed contacts 61, the movable contactor 63 of a time delay relay 65, a conductor 67, the primary 69 of the ignition transformer 71, a conductor 73 to the bus bar 43 of the supply line. It is to be noted that the upper movable contactor 45 of the second relay 41 operates to lock in the relay through the conductor 37, thus rendering the lower movable contactor 31 of the first relay 33 unnecessary as long as the room thermostat 21 remains closed.

Potential is now supplied to the spark gap 19 in a circuit extending from ground through the secondary 75 of the ignition transformer 71, a conductor 77, the ignition spark 19, a conductor 79 to ground through the walls 81 of the fire box 7. In parallel with the ignition spark gap 19 an auxiliary spark gap 83 is connected between the conductor 77 and ground. The auxiliary spark gap 83 is provided with a metallic shield 85 capable of preventing the flow of air currents through the region between the spark electrodes 87. The shield 85 is, of course, spaced from the spark electrodes 87 such a distance that the possibility of a discharge between the walls of the shield and either of the electrodes is precluded. In practice, moreover, one of the electrodes 87 is connected to the "hot" terminal of the secondary 75 through the conductor 77 while the other electrode 87 is connected to the shield 85 which is, in turn, connected to ground.

The electrodes 87 of the auxiliary spark gap 83 are so spaced that if there is any tendency that a comparatively long spark of a quality not particularly adapted to ignite the fuel will be produced across the ignition spark gap 19, the auxiliary spark gap breaks down, thus precluding the excitation of the ignition spark gap.

The conductor 77 between the secondary 75 of the ignition transformer 71 and the ignition spark gap 19 is surrounded in one region by a short hollow conductor 89 which is insulated therefrom and cooperates therewith to produce a capacitor. The hollow conductor 89 is connected to a shield 91 enclosing an electric discharge device 93 provided with an anode 95, a cathode 97 and a control electrode 99 and a gaseous medium. There is in addition an electrode 101 which encloses the anode and is connected to the cathode 97 through a resistor 102. The electrode 101 operates to improve the operation of the discharge device, but this electrode is of no consequence here and will not be further discussed. The anode 95 of the discharge device 93 is connected to ground so that a complete circuit exists which includes the secondary 75, the conductor 77 connected to it, the capacity formed by the short hollow cylinder

89 and the conductor 77 of the capacitor between the shield 91 enclosing the discharge device 93 and the cathode 97 of the discharge device and the capacities between the electrodes of the discharge device and ground through the anode 95. In the practice of my invention, it is preferred that a discharge device 93 be selected in which the cathode 97 is of hollow cylindrical structure concentric with the shield 91, so that the capacity between the shield and the cathode is of considerable magnitude.

For ignition of the fuel, it is important that the spark gap have precisely the proper structure. The fuel will fail to ignite.

1. If the gap is too short,

2. If there is insulation failure in the secondary circuit of the transformer 71 or in the spark gap conductors 77 or 79,

3. If there is an open circuit in any part of the secondary circuit of the transformer 77,

4. If the spark gap is too wide.

On the occurrence of a spark capable of igniting the fuel at the ignition spark gap 19, a high frequency field is produced in the capacitor formed by the hollow cylinder 89 and the conductor 71 and this field is transferred to the discharge device and causes the gas therein to become ionized.

In contingencies 1, 2 and 3, gap 19 is, of course, of no utility for ignition; however, the discharge device 93 will not become energized and in time thermal switch 51 will be opened and remain open until the system is serviced. Contingency 4 would result in the excitation of the discharge device 93 were not the auxiliary gap 83 present. In the latter case, the spark is produced between the auxiliary electrodes 87 and not between the electrodes 103, and since the auxiliary electrodes 87 are shielded from air currents, no high frequency field sufficient to ionize the gas in the discharge device 93 is produced.

The shield 85 suppresses the generation of a high frequency field sufficient to energize the tube 93 because it prevents the ionization gap 87 from becoming appreciably reduced as the potential supplied thereto periodically passes through zero. This will be understood if the mechanism of the excitation of the gap is considered. The gap 87 is supplied with alternating potential from the secondary 75 of the ignition transformer 71. Initially the gap is substantially deionized and when the alternating potential is impressed thereon, a discharge is produced between the electrodes 87 only after the potential has risen to a relatively high value. Accordingly, the wave front of the discharge which takes place in the first half period of the potential supplied by transformer 71 is very steep. A periodic discharge having a very steep wave front has a large number of high-frequency harmonics of considerable amplitude, and, therefore, would tend to produce the high-frequency field necessary to cause the energization of tube 93. If the discharge through gap 87 in the half periods of the source 71 following the first discharge also occurred late in the half periods, a periodic discharge of this type would be produced and the tube 93 would be energized. However, this would be the case only if the gap 87 is quickly deionized when the potential of the source 71 passes through zero. If the ionization within the gap 87 is substantial just after the potential has passed through zero, the gap is reenergized at a relatively small value of the potential, and the repeated excitation of the gap in the successive half periods does not have the steep wave front required to produce the high-frequency field. It is seen from the above analysis that if the gap 87 is not to produce a high-frequency field, quick deionization within the gap after the arc is extinguished should be avoided. The deionization of a spark gap after the potential impressed across it has passed through zero is expedited by the flow of air currents which remove the ions from the neighborhood of the gap. The quick deionization may, therefore, be prevented by shielding the gap from air currents, and this object is accomplished by the shield 85 around the gap 87.

Since the device 93 thus remains non-conducting after the gap 83 is energized the system fails to operate until the necessary adjustment is made. The necessity of the particular adjustment will be manifest to a service man when he observes the auxiliary spark gap 83 in operation. In some cases, it may be desirable to provide a signalling device in the auxiliary spark gap circuit.

Let us now assume that the ignition spark gap 19 is of the proper character. In such a case, the gas in the discharge device 93 is ionized and a discharge is produced between the anode 95 and the cathode 97 under the influence of a potential supplied through a suitable transformer 105. The discharge current flows through the current limiting resistor 106, the exciting coil 107 of the first relay 33, and conductor 108 operating the relay.

Current now flows in a circuit extending from the bus conductor 23 through the conductor 25, the room thermostat 21, the conductor 27, the upper movable contactor 45 of the relay 41, the conductor 48, the conductor 50, the conductor 37, the contacts 49 and 53 of the thermal switch 51, the conductor 55, the exciting coil 109 of the time delay relay 65, the upper movable contactor 111 of the first relay 33 which is now engaged with a plurality of corresponding fixed contacts 113, a conductor 115, the motor 17, a conductor 117 to the lugs 43 of the source. The motor 17 operates the blowers 15 and fuel mixed with air is supplied between the ignition spark electrodes 103.

If the fuel is ignited, the conductive flame path operates as a connection between the control electrode 99 and the anode 95 of the discharge device 93 through ground and through a suitable flame electrode 119 which is connected to the control electrode. The capacitor 120 is so adjusted that the discharge device is now maintained energized not only by the high frequency field of the ignition spark but by the conductive flame.

The time delay relay 65 is provided with a timing element 121 which renders it slow to pick up but fast to drop out. Accordingly, after the supply of current to the motor 17 has continued for an interval of time determined by the timing element 121, the relay 65 picks up and opens the primary ignition circuit, thus deenergizing the ignition transformer 71. If the flame has been ignited, the discharge device 93 will now be maintained energized by reason of the conductivity of the flame alone and the first relay 33 will be maintained energized, thus maintaining the time delay relay 65 also energized. If, on the other hand, the flame has not been ignited, the first relay 33 will now immediately become deenergized, since the discharge device 93 will be deenergized and immediately the time

delay relay 65 will drop out, reenergizing the ignition circuit.

The time delay relay 65 may thus successively pick up and fall out several times. The number of times that it picks up and falls out is determined by the thermal switch 51. The time of operation of the latter is generally adjusted to such a value that the time delay relay 65 may pick up and fall out three or four times in the absence of a flame before the thermal switch 51 opens. However, eventually the heater 57 of the thermal switch becomes sufficiently energized to cause the contacts 49 and 53 of the thermal switch to open. The switch 51 is locked in the open position by latch 123 and at this point further operation of the ignition system is prevented and whatever adjustment is necessary must be made.

If the flame has been ignited, the first relay 33 remains energized and the ignition remains turned off until the room thermostat 21 opens, opening the lock-in circuit for the second relay 41. When the relay 41 is deenergized, its upper movable contactor 45 disengages the corresponding fixed contacts 47 and the motor circuit is opened, interrupting the supply of fuel. The flame is now extinguished and the discharge device 93 is deenergizing the first relay 33. The lower movable contactor 31 of the relay 33 then engages its corresponding fixed contacts 125 and prepares the apparatus for subsequent operation when the room thermostat 21 should again close.

If it should happen that the flame terminal 119 is directly short-circuited to ground through the walls 81 of the fire box as, for example, by breaking, the control electrode 99 of the discharge device 93 remains connected to the anode 95 when the flame is extinguished, and the discharge device remains energized. The first relay, therefore, also remains energized and when subsequently the room thermostat 21 closes, the circuit through the thermostat and the second relay 41 now remains open since the lower movable contactor 31 of the first relay 33 is disengaged from its corresponding fixed contacts 125. The burner, therefore, fails to operate until the leakage is removed. Attention is called to the fact that the same situation would exist if the short circuit is established while the flame is extinguished. In such a case, the relay 33 would become energized and prevent later ignition of the flame. In either case, the service operator will recognize from the condition of discharge device 93 where the difficulty resides.

The flame electrode 119, moreover, carries a pair of insulating discs 201 over which a conducting sleeve 203 is slipped. The sleeve 203 is inserted in another sleeve 205 of insulating material and the whole assembly is mounted in the walls 81 of the fire box 5. A conductor 209 connects the conducting sleeve 203 to the cathode 97 of the discharge device 93.

The flame electrode 119 can be short-circuited to ground through the walls 81 by reason of soot deposit through the sleeve 203. Hence the sleeve 203 is connected by the soot either to the electrode 119, to ground or both to ground and the electrode 119. In the first case, the control-electrode 99 is connected to the cathode 97 through conductors 207 and 209. In the two latter cases, the anode is connected to the cathode through ground and the conductor 207. In any case, the discharge device 93 is at once deenergized so that relay 33 is deenergized and the suppply of fuel is interrupted.

Of course the discharge device 93 is also deenergized if when the electrode 119 breaks it contacts the sleeve 203 rather than a wall of the fire box.

It is to be noted that when the discharge device 93 is deenergized, and the relay 33 drops, the ignition transformer 71 is reenergized. The terminal leakage produced by soot is of course equivalent to a high resistance in its electrical properties. The resistance may be so low that the potential difference between anode 95 and cathode 97 is small. In such a case, the discharge device 93 will not become energized by reason of the high frequency potential from the ignition spark and after some time thermal switch 51 will operate. If the resistance of the soot is high, the potential difference between the electrodes 95 and 97 of discharge device 93 may be such that the high frequency field from the spark gap energizes the discharge. In such a case, the flame will be ignited, extinguished and ignited, and the ignition transformer deenergized and reenergized several times before the thermal relay 51 finally operates.

It is to be noted that several changes can be made in the system as disclosed herein. For example, under certain circumstances the discharge device 93 need not necessarily be of the gaseous type. It may be of the high vacuum type containing so little gas that it is responsive to the high frequency field of the spark but does not operate as the usual arc-like discharge device with an abrupt lock-in characteristic.

Although I have shown and described a certain specific embodiment of my invention, I am fully aware that many modifications thereof are possible. My invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and by the spirit of the appended claims.

I claim as my invention:

1. Combustion control apparatus comprising means for supplying a fuel to be burned, means, including a spark gap, to ignite said fuel, a first circuit for supplying potential to produce and maintain a spark in said gap, an electric discharge device for controlling said supplying means, a second circuit for supplying energy to said electric discharge device, means for so coupling said first and second circuits that said discharge device is energized by reason of the high frequency field produced by a spark in said gap and means for preventing the occurrence of a spark in said gap such as would energize said discharge device energized when the gap is too wide to produce a proper ignition spark for combustion.

2. Combustion control apparatus comprising means for supplying a fuel to be burned, means, including a spark gap, to ignite said fuel, a first circuit for supplying potential to produce and maintain a spark in said gap, an electric discharge device for controlling said supplying means, a second circuit for supplying energy to said electric discharge device, means for so coupling said first and second circuits that said discharge device is energized by reason of the high frequency field produced by a spark in said gap, means in said second circuit for actuating said fuel supply means to initiate the supply of fuel when said discharge device is energized, and means for preventing the occurrence of a spark in said gap such as would energize said discharge device when the gap is too wide to produce a proper spark for combustion.

3. Combustion control apparatus comprising means for supplying a fuel to be burned, means, including a spark gap, to ignite said fuel, a first circuit for supplying potential to ignite and maintain a spark in said gap, an electric discharge device having a plurality of electrodes, a second circuit for supplying energy to said electric discharge device, means for so coupling said first and second circuits that said discharge device is energized by reason of the high frequency field produced by a spark in said gap, means in said second circuit for actuating said fuel supply means to initiate the supply of fuel when said discharge device is energized and means responsive to the presence of a leakage current through a path in the region of said flame that is present in the absence of said flame for causing said discharge device to become deenergized, the said responsive means operating to interconnect the said path and certain of said electrodes.

4. Combustion control apparatus comprising means for supplying a fuel to be burned, means, including a spark gap, to ignite said fuel, a first circuit for supplying potential to ignite and maintain a spark in said gap, an electric discharge device having a plurality of electrodes, a second circuit for supplying energy to said electric discharge device, means for so coupling said first and second circuits that said discharge device is energized by reason of the high frequency field produced by a spark in said gap, means in said second circuit for actuating said fuel supply means to initiate the supply of fuel when said discharge device is energized, and means responsive to the presence of a leakage current in a path in the region of said flame that is present in the absence of said flame for deenergizing said discharge device independently of the presence or absence of said flame, the said responsive means operating to interconnect the said path and certain of said electrodes.

5. Control apparatus comprising spark gap means, an electric discharge device for controlling a combustible material to be ignited by said spark gap means, means for coupling said spark gap means to said electric discharge device in such manner that the high frequency field produced by a proper ignition spark in said spark gap means causes said electric discharge device to become energized and means for preventing an improper ignition spark in said spark gap means which if not prevented would still produce a high frequency field capable of energizing said discharge device.

6. Apparatus according to claim 5 characterized by the fact that the preventing means is a second spark gap connected to have a spark produced therein when the spark in the first-mentioned spark gap would have a length greater than a predetermined value.

7. Apparatus according to claim 5 characterized by the fact that the preventing means is a second spark gap connected to have a spark produced therein when the spark in the first-mentioned spark gap would have a length greater than a predetermined value, and means for shielding said second spark gap from air curents.

8. Apparatus for controlling combustion of fuel in a region comprising, ignition means for said fuel, means responsive to a flame in the region for maintaining the supply of fuel to said flame, means energizable independently of said responsive means and having a plurality of positions for interrupting the supply of fuel when in one of said positions and permitting the supply of fuel and the operation of said ignition means when in another of said positions and means cooperative with said independently energizable means, when it is in said last-named position, for reinitiating the supply of fuel and the operation of said ignition means after said fuel supply has been interrupted, said responsive means including means responsive to an electrical conductive path in the region of said flame other than that of the flame conductive path and energizable independently of the position of the means having a plurality of positions for preventing the operation of said fuel-supply reinitiating means and said ignition means.

9. Combustion control apparatus comprising means for supplying a fuel to be burned, means, including a spark gap, to ignite said fuel, a first circuit for supplying potential to ignite and maintain a spark in said gap, an electric discharge device, a second circuit for supplying energy to said electric discharge device, means for so coupling said first and second circuits that said discharge device is energized by reason of the high frequency field produced by a spark in said gap and means for preventing said discharge device from becoming energized when the gap is too wide to produce a proper spark for combustion, said preventing means comprising a second spark gap connected in parallel to the fuel igniting spark gap in the first circuit and shielded from air currents so that it does not produce a high frequency field tending to energize the discharge device.

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