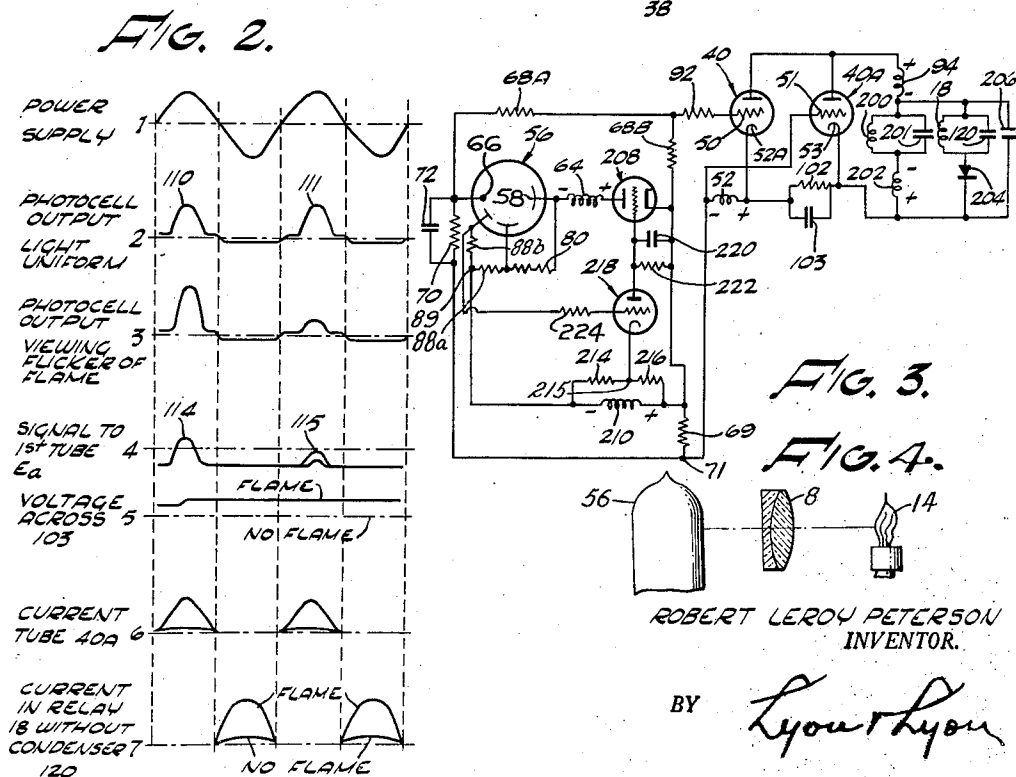
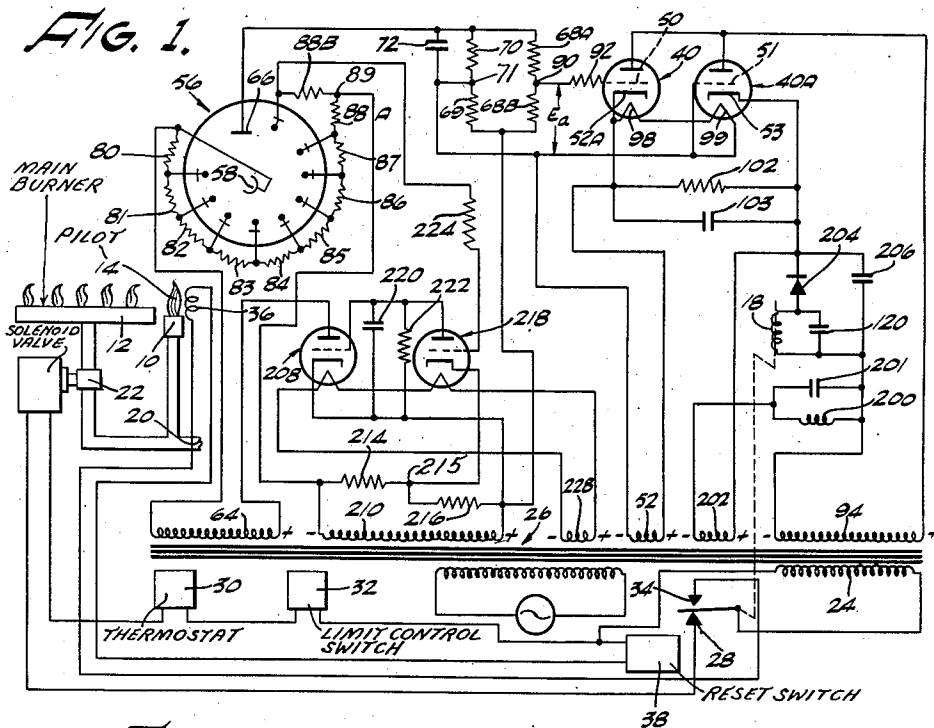


Aug. 18, 1959

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SYSTEM FOR DERIVING AVERAGE INTENSITY OF FLAME AND
COMPARING INSTANTANEOUS INTENSITY THEREWITH
INCORPORATING AUTOMATIC GAIN CONTROL
Filed Oct. 22, 1953

2,900,524



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SYSTEM FOR DERIVING AVERAGE INTENSITY OF FLAME AND COMPARING INSTANTANEOUS INTENSITY THEREWITH INCORPORATING AUTOMATIC GAIN CONTROL

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Application October 22, 1953, Serial No. 387,750

7 Claims. (Cl. 250—214)

The present invention relates to an improved control system which includes an amplifier associated with flame-sensing means and in general constitutes an improvement in the system described and claimed in my copending patent application Serial No. 356,501, filed May 21, 1953, and assigned to the present assignee.

Briefly, the arrangement described herein incorporates an automatic gain control circuit for use in a system described in my above-mentioned copending application and also to improved amplifier circuitry. In general, the arrangement described herein functions to cause a load, such as a relay winding, to be fully energized when a flame is present, the relay being automatically de-energized when the flame fails to continue to burn. The flame-sensing device, as shown herein, comprises a photoelectric cell with associated gain control circuitry for deriving an electrical quantity which is representative of the average intensity of a pilot flame and comparing the instantaneous intensity of the pilot flame with such average intensity to derive a control voltage, such control voltage being effective to maintain a load, such as a relay, energized so long as the flame is present. In other words, the apparatus as described herein is sensitive to sporadic fluctuations or flicker of a flame and serves to develop a control voltage so long as the pilot flame is present, as evidenced by the flicker or fluctuation in intensity which is inherent from the nature of the pilot flame.

It is, therefore, a general object of the present invention to provide apparatus of the character described above which incorporates gain control circuitry.

Another general object of the present invention is to provide improved amplifying means which is not necessarily limited to use with the present flame-sensing apparatus.

Another object of the present invention is to provide an improved system of this character which serves, in general, to derive the voltage which may be considered to represent the average intensity of a flame, and for comparing such average voltage with a fluctuating voltage representative of the instantaneous intensity of the flame, and to produce a control voltage as a result of such comparison using a photoelectric cell having associated therewith gain control circuitry.

Another object of the present invention is to provide apparatus of this character which is relatively simple and inexpensive.

Another object of the present invention is to provide apparatus of this character which is insensitive to fluctuations or variations in the power supply frequency.

Another specific object of the present invention is to provide apparatus of the character indicated in the preceding paragraphs featured by the fact that the apparatus is energized solely from an alternating current source without the requirement of a direct current source.

Another object of the present invention is to provide apparatus of this character which does not require shielding of the leads which lead to the flame sensing device

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since any electromagnetic or electrostatic pickup in such leads from the alternating current source has substantially no effect on the operation of the circuitry.

Another object of the present invention is to provide means and techniques of this character which detects presence of a flame by what may be termed to be a "sampling" process, the intensity of the flame being periodically measured or sampled during alternate half cycles of an alternating current wave, and the intensity compared with an average intensity derived from preceding sampling.

Another object of the present invention is to provide apparatus of this character in which the control may function under different conditions and a relatively large range of light intensities produced either by gas or oil flames.

Another object of the present invention is to provide apparatus of this character in which the control is relatively insensitive to line voltage variations and thus may be operated successfully even when the line voltage is subjected to large fluctuations.

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. This invention itself, both as to its organization and manner of operation, together with further objects and advantages thereof, may be best understood by reference to the following description taken in connection with the accompanying drawings in which:

Figure 1 illustrates apparatus in schematic form which embodies features of the present invention;

Figure 2 illustrates the relationship of various currents and voltages in the apparatus illustrated in Figure 1;

Figure 3 shows, in simplified form, some of the apparatus illustrated in Figure 1;

Figure 4 illustrates the manner in which the photocell is located to receive radiation from the pilot flame 14 in the arrangement shown in Figure 1.

The apparatus shown in Figure 1 operates so as to allow the flow of gas to a pilot burner 10 and an associated main burner 12, only so long as a pilot flame 14 is present. The presence of such pilot flame is evidenced by the inherently produced fluctuations in intensity or flicker; the apparatus as described herein is sensitive to such fluctuations or flicker. In general, as long as the pilot flame 14 is present, the relay winding 18 remains energized, as shown in Figure 1, to allow gas to flow from the gas inlet 20, through the solenoid operated valve 22, to the main burner 12. This condition exists when the solenoid valve is energized with current which flows in the following series circuit: the secondary winding 24 of transformer 26, the relay switch 28, the solenoid valve 22, the thermostat 30, and the limit control switch 32.

As indicated previously, when there is no pilot flame 14, the relay winding 18 is de-energized in which case the relay switch 28 is opened and the relay switch 34 is closed. In this particular condition, the gas escaping from the pilot burner 10 may be ignited by the electrically heated ignitor coil 36 which is supplied with heating current flowing in the following series circuit: secondary winding 24, switch 34, ignitor coil 36 and the conventional manually operable reset switch 38 having thermal cutoff.

In the absence of the flame 14, both tubes 40 and 40A are each in a nonconducting state. This condition exists since the control grid 50 of tube 40 as well as the control grid 51 of tube 40A are each connected to the so-called negative terminal of the secondary transformer winding 52, while the cathodes 52A and 53, respectively, of tubes 40 and 40A are each returned to the so-called positive terminal of source 52. Although the winding 52 is, of course, a secondary transformer winding and has an alternating current voltage induced there-

in, one terminal is referred to as a negative terminal while the other terminal is referred to as a positive terminal. This designation is arbitrary and signifies the polarity of the respective terminals of the transformer windings at that particular time when various portions of the apparatus conduct current. It is observed, with reference to Figure 2, that although the apparatus is energized exclusively from an alternating current source, conduction currents in various portions of the apparatus flow from the transformer secondary windings only during one-half cycle of the alternating current wave. During such one-half cycle when there is conduction, the terminals of the secondary transformer windings have the polarity as indicated in Figure 1.

Thus, in order to render the tubes 40 and 40A conductive, it is necessary that the negative bias voltage supplied by the secondary winding 52 be overcome. This negative voltage, indeed, is overcome when the flame 14 is present as described below. The photo-electric cell 56 which is of the 931A type receives light from the pilot flame 14. The cathode 58 of the cell 56 is connected to the negative terminal of the transformer secondary winding 64. Winding 64 has its positive terminal connected to the anode of the variable resistance tube 208, the cathode of tube 208 being connected through two parallel connected circuits to the cell anode 66. One of such circuits comprises the series connected resistances 68B and 68A; and the other parallel circuit comprises the series connected resistances 69 and 70. The resistance 70 is shunted by condenser 72 and the junction point 71 of resistances 69 and 70 is connected, on the one hand, to the negative terminal of winding 52, and on the other hand, to the control grid 51 of tube 40A.

The various so-called dynodes of the photo-multiplier tube of tube 56 are connected to various points in a voltage dividing network having opposite terminals thereof connected, on the one hand, to the negative terminal of winding 64, and on the other hand to the control grid of the control tube 218 through resistance 224. Such voltage dividing network comprises the resistances 80, 81, 82, 83, 84, 85, 86, 87, 88A and 88B. The junction point 89 of resistances 88A and 88B is connected to the negative terminal of the secondary winding 210. A voltage dividing network comprising resistances 214 and 216 is connected across opposite terminals of the secondary winding 210 and the junction point 215 of resistances 214 and 216 is connected to the cathode of control tube 218 whereby the voltage developed across the resistances 88B is applied between the control grid and the cathode of the control tube 218. This voltage developed across resistance 88B is used for automatic gain control as described later. It is observed that the resistance 80 is connected between the cathode 58 and the first dynode; the second resistance 81 is connected between the first and second dynodes, and so forth, as shown in Figure 1. The anode of control tube 218 is connected directly to the control grid of the variable resistance tube 208. A condenser 220, as well as a resistance 222, is connected between the control grid and the cathode of tube 208, such cathode being connected to the positive terminal of the transformer secondary winding 210. It is observed at this time that the resistance 222 is connected in the space current path for tube 218, as well as in the control grid circuit of tube 208, so as to obtain an automatic gain control function in more detail later.

The anodes of tubes 40 and 40A are each connected to the positive terminal of the secondary transformer winding 94, the negative terminal of winding 94 being returned to the cathode 53 of tube 40A through a series circuit which includes the saturable reactor winding 200, the transformer secondary winding 202 and the cathode 53, condenser 201 being connected in shunt with the winding 200 and the positive terminal of transformer

secondary winding 202 being connected to the cathode of tube 53. The cathodes of tubes 40 and 40A are interconnected by a resistance 102 which is shunted by condenser 103. It is observed that the resistance 102 is thus in the space current path for tube 40 and likewise, such resistance 102 is connected between the control grid and cathode of tube 40A.

The relay winding 18 is interconnected in a series circuit with rectifier 204, transformer secondary winding 202 and saturable reactor 200, the rectifier 204 being poled so that current is allowed to flow in this aforementioned series circuit only during those alternate half cycles when the tubes 40 and 40A are nonconducting (assuming the presence of a flame 14). A filter condenser 120 is connected in shunt with relay winding 18 to prevent chattering of the associated relay contacts. Condenser 206 is connected in shunt with the series circuit which comprises relay winding 18 and rectifier 204.

The heaters 98 and 99 for the cathodes 52A and 53, respectively, of tubes 40 and 40A are connected in series with the aforementioned winding 52.

It is noted that the cathode 52A of tube 40 is returned to the negative terminal of winding 94 through the parallel connected resistance 102 and condenser 103, which resistance and condenser, as mentioned previously, are connected in the grid cathode circuit of tube 40A. The voltage thus developed across the parallel connected resistance 102 and condenser 103, in operation of the arrangement, as described later, constitutes a so-called enabling voltage which enables the tube 40A to become conductive, it being noted previously that the voltage developed in the secondary winding 52 maintains the tube 40A in a nonconducting condition in the absence of a flame.

The circuitry thus far described consists essentially of a light pick-up tube namely the photo tube 56, a discriminating network which involves the elements 68A, 68B, 69, 70 and 72, and a two-stage vacuum tube amplifier comprising tubes 40 and 40A.

Since the photo tube 56 is operated from an alternating current supply, the output of such cell is in the form of pulses, one pulse occurring each cycle of the power supply as indicated in Figure 2. Since the light output of the pilot flame 14 fluctuates in intensity or flickers, the magnitude or intensity of successive current pulses through the photocell is not the same, but varies as indicated in curve 3 of Figure 2. Assuming that the flame produces a light which is constant in intensity (which is not the case), the current flowing through the photocell is then in the form illustrated in curve 2 of Figure 2 which shows each current pulse of the same height, i.e., same magnitude or intensity. These values of current represented in curve 2 are, however, considered to be an average; and it is understood, that in operation of the arrangement, the apparatus is so adjusted that photocell current pulses having a magnitude of intensity greater than such average produces a certain effect, whereas current pulses flowing through the photocell having a magnitude less than such average produces an effect which is opposite to the aforementioned certain effect.

The circuitry is so adjusted to provide pulses of a suitable magnitude for the particular condition of the pilot flame 14. When the photo tube 56 views such flame, it is understood, as mentioned above, the magnitude of the current pulses flowing from the anode 66 to the cathode 58 varies. Thus, some pulses will be larger than the average and some will be smaller than the average as illustrated in curve 3 of Figure 2.

The average value of such current pulses is represented by the voltage developed across the condenser 72. The resistances 68A and 68B are so proportioned that the peak magnitude of pulse output is just equal to the average voltage on condenser 72. Thus, the voltage represented as E_a in Figure 1 is normally negative and is zero at one instant in the cycle, assuming a uniform light in-

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tensity on the photo tube is represented by the peaks of equal intensity 110, 111 in Figure 2. Fluctuations in light intensity or flicker, cause some of the pulses to be larger than the average and some to be smaller than the average as illustrated in curve 3 of Figure 2 to, in turn, produce corresponding signals as indicated at 114, and 115 in curve 4 of Figure 2. The signal 114 causes the tube 40 to conduct, whereas the signal 115 is of insufficient intensity to cause the tube 40 to conduct. Thus, the tube 40 conducts at what may be termed to be a random rate, depending upon whether the light intensity, each succeeding one-sixtieth of a second in the case of a sixty cycle per second power supply, is either above or below a certain average.

While the tube 40, in the presence of a flame, conducts at a random rate, the relay control tube 40A is continuously energized as a result of the voltage developed across the condenser 103 connected in shunt with the resistance 102, it being noted that the elements 102, 103 are in the space current path for the first tube 40 and that the condenser 103 assumes a charge, i.e., a voltage, which represents an average condition. This voltage developed across condenser 103 is represented in curve 5 in Figure 2. As a result, the current flowing through tube 40A, and through the reactor winding 200, is illustrated in curve 6 in Figure 2 wherein the current pulses 118 are of sufficient magnitude to cause the relay winding 18 to be fully energized, as described above, i.e., to cause the relay switch 28 to be maintained in its closed position as shown in Figure 1.

These current pulses 118 condition the magnetic circuit of the saturable reactor winding 200 so that in the next succeeding half cycle (when the tubes 40 and 40A are in a nonconducting state) sufficient current flows through the following series circuit to maintain relay winding 18 fully energized as described above, such series circuit comprising winding 202, reactor winding 200, relay winding 18, and rectifier 204. The current flowing through such relay winding 18 is represented by curve 7 in Figure 2.

It is observed that since operation of the arrangement depends on the pulse height, i.e., amplitude of photocell pulses, varying on different pulses, the arrangement does not respond to fluctuations in the power supply frequency. This is considered to be an advantage because normally the prime fluctuation or flicker frequency of a gas flame is approximately five cycles per second (much lower than the power supply frequency) and thus any electromagnetic or electrostatic, or otherwise pick-up of a power frequency component in the photocell leads has substantially no effect on the operation of the circuitry.

Without limiting the scope of the present invention, and for illustrative purposes only, the various designated components may, for example, have the following values: condenser 72 may be .05 to .1 microfarad; resistances 69 and 70 may each have a value of five megohms; the combined resistance of resistance elements 68A and 68B may be five to ten megohms; resistance 92 which is connected between the control grid of tube 40 and the junction point of resistances 68A and 68B may be five megohms; resistance 102 may be 100,000 to 500,000 ohms; condenser 103 may be four to five microfarads.

The circuitry is thus, not only insensitive to frequency variations in the fundamental of the power supply frequency, but is likewise insensitive to harmonics of the fundamental since the arrangement is essentially a pulse measuring arrangement, and in the case of power frequency pick-up, the pick-up has the same effect on each pulse whereas the flame produces an amplitude or height variation in essentially each photocell current pulse.

It is evidenced from the above that during the nonconducting half of the alternating current cycle (with respect to tubes 40 and 40A) the precharged condenser 72 establishes certain voltage conditions in the series circuit which includes the resistances 68A, 68B and 69 and

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such voltage conditions, thus established, may be considered to represent the average intensity of the sporadic fluctuations of the flame. This voltage, under these conditions, serves to render the upper terminal of the resistance 69 in Figure 3 more negative than the lower terminal, i.e., the condenser discharge voltage developed across the resistance 69 is in additive relationship with the voltage developed in the transformer winding 52 so that this average voltage acts in such a direction to bias the tube 40 further for cut-off.

On the conductive half cycle a pulse is produced in the network which includes the cell 56, the winding 64, tube 208 and resistances 68B and 68A, such pulses producing a voltage across the resistance 68B and 68A which may be considered to represent the instantaneous intensity of the flame. In effect, this voltage, representing respectively the average intensity and instantaneous intensity, is compared and the resultant is applied between the control grid and cathode of the tube 40 to cause the tube to conduct only when the instantaneous intensity of the flame during the conductive half cycle of the tube is greater than the average intensity.

It is observed further that the average voltage thus developed automatically changes in level, depending upon flame conditions. In other words, the condenser 72 is periodically discharged and is charged and assumes an average voltage which is variable, depending upon the flame conditions. Further, the photocell 56 in certain installations may be so arranged that it receives radiation from either the flame from the main burner 12 or the flame from the pilot burner 10, or such photocell may receive radiation from the main burner and from the pilot burner simultaneously.

In accordance with an important feature of the present invention, circuitry is incorporated for minimizing or eliminating the effect which variations in intensity of the supply voltage would produce. This circuitry involves the variable resistance tube 208 and the control circuitry associated therewith, including tube 218.

As indicated previously, the voltage which is developed representing the instantaneous intensity involves circuitry including the variable resistance tube 208. The resistance of this tube 208 is controlled with respect to the intensity of the supply voltage, i.e., that voltage which is applied to the primary of the transformer and which causes a voltage to be developed across the secondary winding 64. The circuitry operates in such a manner that the higher the voltage developed in winding 64, the higher the resistance of tube 208, so that the voltage drop across the network, which includes resistances 68A and 68B, is substantially independent of variations in the magnitude of the supply voltage. When the magnitude of the supply voltage increases, the voltage developed across the winding 64 likewise increases with the result that there is a tendency for an increased voltage to appear between the cathode 58 and the anode 66 of the phototube 56 to in turn produce an increased current flow through resistance 88B which is connected in the grid cathode circuit of the control tube 218, the control grid of tube 218 being biased negatively in accordance with the voltage developed across resistance 214. This assumed increased voltage drop across resistance 88B causes the control grid of tube 218 to become more positive to in turn produce an increased current flow through the space current path of tube 218 which includes the resistance 222, and as a result, the anode of tube 218 and the connected control grid of tube 208 are rendered more negative to thereby increase the resistance of tube 208. Thus, the circuit, which includes winding 64, tube 208, resistance 68B and 68A and phototube 56 is essentially a constant current circuit, the current being maintained substantially constant by changing the resistance of tube 208 in accordance with variations in voltage in the winding 64; thus, an automatic gain control circuit is incorporated, such gain control circuit consists of a two-stage amplifier responding to the output

level of the phototube to control the supply voltage to the dynodes of the phototube 56. The phototube output, which appears across resistance 88B is applied to the control grid of tube 218 with the voltage across resistance 214 serving as a bias. When the signal exceeds the bias level, tube 218 conducts, it being noted that in the absence of a flame, tube 218 is rendered nonconductive by the bias voltage developed across resistance 214. In the presence of a flame, the current flows through resistance 222 and a voltage is developed across condenser 220. This voltage developed on condenser 220 causes tube 208 to conduct to a lesser degree, thereby reducing the voltage applied to the dynodes. Thus, the current flowing to the photocell is reduced. The resistance 222 and condenser 220 form a time delay circuit to provide a sufficient time delay during which light variations of the flame itself cause the amplifier proper, including tubes 40 and 40A to function as described above. In the absence of a flame, there is substantially no radiation impinging on tube 56 and hence, the voltage drop across resistance 88B is considered to be zero, which means that the tube 218 is in a nonconducting state as indicated above. Consequently, under this condition, there is no current flow through the resistance 222, or the condenser 220 and substantially no voltage is developed across condenser 220, with the result that the tube 208, under these conditions, is conditioned to conduct relatively heavily, i.e., its resistance is relatively low. Immediately after initiation of a flame the condenser 220 is charged in steps, i.e., accumulates additional charge during successive alternate half cycles of the power supply frequency until the condenser 220 assumes its full charge. It is during these first cycles, during which the condenser 220 is charged in steps, that the desired time delay occurs.

While the particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from this invention in its broader aspects and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

I claim:

1. In a flame detecting apparatus of the character described, a first device having a cathode control grid and an anode, a first transformer winding connected between said cathode and said anode, a second transformer winding connected between said cathode and said control grid and poled such that in the absence of a flame it renders said control grid negative when said anode is positive to thereby render said device normally nonconductive, means connected between the cathode and control grid for developing a voltage representative of the average intensity of a sporadically fluctuating flame, the last mentioned means, incorporating means, for rendering said device conductive when said flame intensity is above a predetermined average level and incorporating a photoelectric cell energized from an alternating current source, said cell having an electrode connected to said source and controlling said voltage developing means in accordance with the radiation impinging on said cell, and means connected to and responsive to the voltage on said electrode for controlling the current through said cell so as to render the output of said photoelectric cell substantially independent of variations in the magnitude of the voltage of said source.

2. In a flame detecting apparatus of the character described, a device having a cathode, a control grid and an anode, a photoelectric cell subjected to sporadic fluctuations in intensity of a flame, a first transformer winding connected between said cathode and said anode, a second transformer winding connected between said cathode and said control grid and being so poled that said second winding tends, in the absence of a flame, to maintain said control grid negative when said anode is positive to thereby render said device nonconducting, a third transformer

winding, a potentiometer resistance having a tap thereon connected to said control grid and having opposite terminals thereof connected in series with said cell and said third winding, a second and a third resistance connected in series with their junction point connected to one terminal of said second winding, the other terminal of said second winding being connected to said cathode, said second and third resistances being connected in shunt with said cell, the junction point of said third resistance with said third winding being connected to one terminal of said potentiometer resistance, a condenser connected in shunt with said second resistance, said condenser having one of its terminals connected to one terminal of said second winding and said condenser having its other terminal connected to the other terminal of said potentiometer resistance, a variable resistance tube connected serially with said third winding and said cell, and means controlling the resistance of said tube in accordance with current flowing through said tube.

3. In flame detecting apparatus of the character described, which is responsive to sporadic fluctuations in said flame, first means deriving a quantity which is representative of the average of said fluctuations, a tube, and second means controlling said tube in accordance with deviations from said average, said first means including a photocell and an energizing circuit therefor subject to voltage variations, said photocell having an electrode connected to said energizing circuit and controlling said first means in accordance with radiation impinging thereon, and means connected to and responsive to the voltage on said electrode for maintaining the average current flow through said photocell substantially constant in spite of said variations.

4. In flame detecting apparatus of the character described which is sensitive to sporadic fluctuations in a flame, a first transformer winding, a second transformer winding, a third transformer winding, a device having a cathode, a control grid and an anode, said first winding being connected between said cathode and said anode, said second winding being connected between said cathode and said control grid to tend to render said control grid negative when said first winding renders said anode positive, a photoelectric cell having an electrode, said third winding being connected in series with said photoelectric cell and arranged to cause said cell to conduct only when said device is rendered conductive by said first winding, a first resistance, a second resistance connected in series with said first resistance and said cell and said third winding, the junction point of said first and said second resistances being connected to one terminal of said second winding, the other terminal of said second winding being connected to said cathode, a condenser connected in shunt with said first resistance, a pair of resistances having their junction connected to said control grid and connected in a series circuit with said cell and said third winding, means energizing said first, second and third windings from a source of alternating current voltage which is subject to variations in voltage, said source being connected to said electrode, and means coupled to and responsive to the voltage on said electrode for maintaining the average current there-through substantially constant in spite of said variations in voltage.

5. In flame detecting apparatus of the character described which is sensitive to sporadic fluctuations in a flame, a device having a cathode, a control grid and an anode, an energizing circuit for an alternating current source, first means connected to said source for rendering said device conductive during alternate half cycles of said alternating current source, a photoelectric cell, having an electrode connected to said source, second means connected to said source for rendering said photoelectric cell conductive during the same half cycles of said source when said device is conductive, third means including said cell for deriving a control voltage in

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accordance with current flow through said cell, fourth means connected to said source for applying a negative voltage, which is in opposition to said control voltage between said control grid and said cathode to render said device conductive only when said control voltage exceeds a predetermined level, said photoelectric cell being subjected to said sporadic fluctuations in said flame, said alternating current source being subject to variations in intensity, and means coupled to and responsive to the voltage on said electrode for changing the current flowing therethrough in accordance with said variations such that the effect of said variations on the current flow through said cell is substantially eliminated.

6. In flame detecting apparatus of the character described which is sensitive to sporadic fluctuations in a flame, a device having a cathode, a control grid and an anode, a transformer winding connected between said cathode and said anode to render said device conductive during alternate half cycles of an alternating current voltage, a second transformer winding connected between said cathode and said control grid intending to maintain said control grid negative when said anode is rendered positive by said first winding, a third winding, a photoelectric cell, a second device, a series circuit comprising said second device, said photoelectric cell and said third winding, said third winding rendering said cell conducting during said half cycles when said device is conducting, a portion of said series circuit being coupled between said control grid and said cathode and developing a control voltage thereacross in accord-

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ance with the intensity of cell current, said control voltage being in opposition to the voltage developed by said second winding and functioning to render said device conducting only when said control voltage exceeds a predetermined level, said cell having a dynode forming a portion of said series circuit, and means controlling the conduction of said second device in accordance with the potential developed on said dynode.

7. In apparatus of the character described, a source of alternating current subject to fluctuations in output voltage, a photocell, a first control device, a first resistance network, a first series circuit comprising: said source, said control device, said resistance network and said photocell; a resistance-capacitance network, a second series circuit comprising: said source, said control device, said resistance-capacitance network and said photocell; said photocell having a dynode, means coupled to said dynode for controlling the resistance of said control device in accordance with the voltage on said dynode so as to maintain the current flow through said photocell substantially constant in spite of said fluctuations, and control means coupled to said first and second series circuits.

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