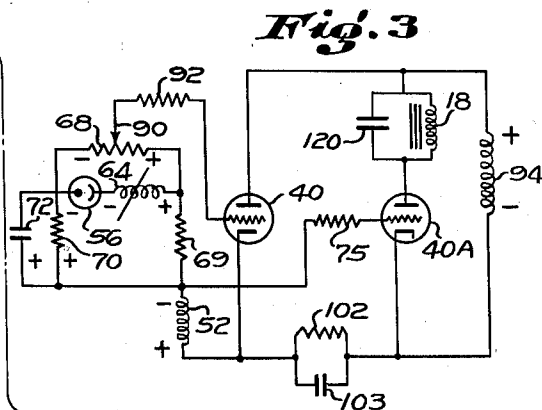
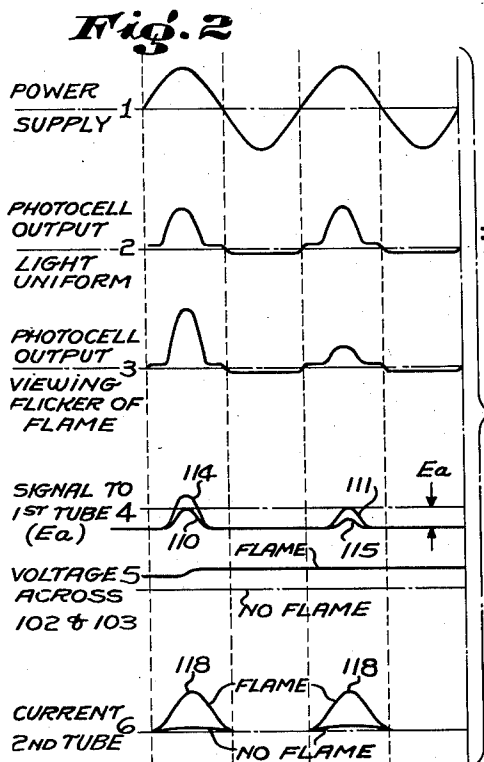
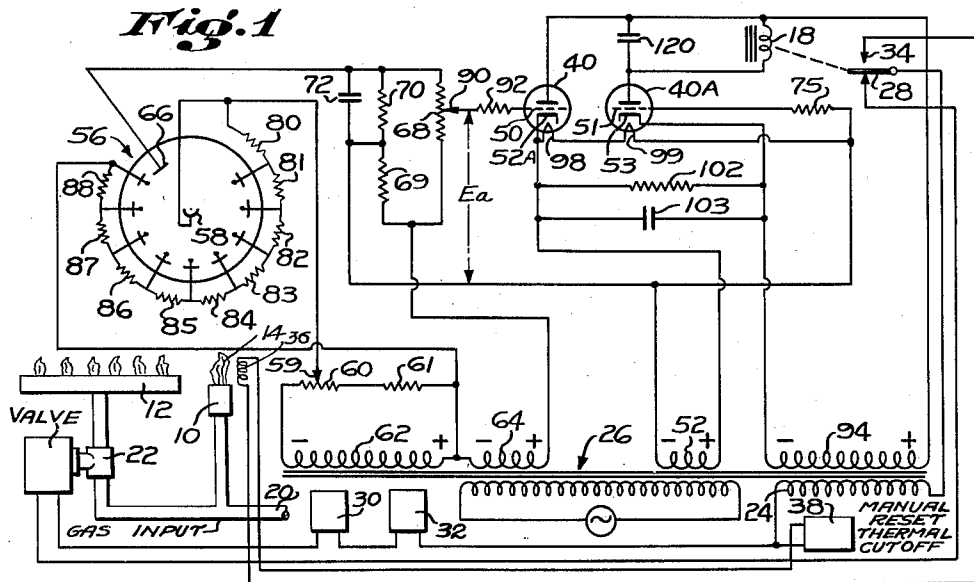


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SYSTEM FOR DERIVING AVERAGE INTENSITY OF FLAME
AND COMPARING INSTANTANEOUS
INTENSITY THEREWITH
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SYSTEM FOR DERIVING AVERAGE INTENSITY OF FLAME AND COMPARING INSTANTANEOUS INTENSITY THEREWITH

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The present invention relates to an improved control system which includes an amplifier associated with flame-sensing means.

Briefly, 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 circuitry for deriving an electrical quantity which is representative of the average intensity of the flame and comparing instantaneous intensity of the 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 fluctuations or flicker of a gas flame and serves to develop a control voltage so long as the flame is present, as evidenced by the flicker or fluctuation in intensity which is inherent from the nature of the flame.

It is, therefore, a general object of the present invention to provide apparatus of the character described above and more fully hereinafter.

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 value with a value representative of the instantaneous intensity of the flame, and to produce a control voltage as a result of such comparison.

Another specific 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 paragraph 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 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 alternating half cycles of an alternating current wave, and the intensity compared with an average intensity derived from preceding sampling.

The features of the present invention which are believed to be novel are set forth with particularity in the appended

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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.

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 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 flame 14 is present, the relay winding 18 remains energized, as shown in Figure 1, to allow gas to flow from the gas inlet line 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 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.

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 52 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 stationary transformer winding and has an alternating current voltage induced therein, 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 winding 52 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 conducting, 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 photoelectric 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 an adjustable tap 59 on resistance 60 which is serially connected with the fixed resistance 61 and the transformer secondary winding 62 so that an adjustable alternating current voltage is obtainable at tap 59. Winding 62 has its positive terminal connected to the negative terminal of winding 64, which

has its positive terminal connected through two parallel connected circuits to the cell anode 66, one of such circuits comprising the potentiometer type of resistance 68, and the other parallel circuit comprising the serially connected resistances 69 and 70. Resistance 70 is shunted by condenser 72 and the junction point 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 through the resistance 75.

The various so-called dynodes of the photo-multiplier type of tube 56 are connected to various points in a voltage dividing network having opposite terminals thereof connected, on the one hand, to the adjustable tap 59, and on the other hand to the junction point of windings 62 and 64. Such voltage dividing network comprises the resistances 80, 81, 82, 83, 84, 85, 86, 87 and 88. 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 adjustable tap 90 on resistance 68 is connected to the control grid 50 through the current limiting resistance 92.

Tube 40 has its anode connected to the so-called positive terminal of the secondary transformer winding 94; and, likewise the anode of tube 40A is connected through the relay winding 18 to the same positive terminal of winding 94.

The heaters 98 and 99 for the associated cathodes of tubes 40 and 40A are serially connected with the aforementioned winding 52.

It is noted that the cathode 52A of tube 40 is returned to the negative terminal of the winding 94 through the parallel connected resistance 102 and condenser 103, which resistance and condenser are connected in the grid-cathode circuit of the 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 non-conducting condition in the absence of a flame.

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

Since the phototube 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 56 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 tap 59 on resistance 60 is so adjusted to provide pulses of a suitable magnitude for the particular condition of the pilot flame 14. When the phototube 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 of photocell 56 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 tap 90 on resistance 68 is so adjusted 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 intensity 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. Signals as indicated at 114 and 115 representing the instantaneous intensity of flame intensity are developed across resistance 68. It is noted that a portion of resistance 68 and the condenser 72 are connected in series between the grid and cathode of tube 40, and that the net voltage developed across these elements determines whether or not the tube 40 conducts. 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 $\frac{1}{60}$ of a second, in the case of a 60-cycle per second power supply, is either above or below a certain average. In other words, tube 40 is rendered conductive depending upon whether the voltage developed across resistance 65 is greater or less, in comparison, to the voltage across condenser 72. Stated in other words, there is a comparison which is effectively made every one-sixtieth of a second, and tube 40 either conducts or does not conduct at that particular time in accordance with such comparison.

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 relay winding 18, is illustrated in curve 6 in Figure 2 wherein the current pulses 118 are of sufficient magnitude to maintain the relay 18 energized, i. e., to cause the relay switch 28 to be maintained in its closed position. In other words, the voltage developed across condenser 103 constitutes an enabling voltage which is referred to above, and which serves to maintain the tube 40A in a conducting state to allow the relay winding 18 to become efficiently energized to maintain the associated relay switches in an actuated condition as represented in Figure 1. Stated in still other words, tube 40 is periodically rendered conductive, in a random manner, when a flame is present, in accordance with the comparison referred to above, but a substantially continuous enabling voltage, as the result of the output of tube 40, is developed across condenser 103, as an enabling voltage; and, this enabling voltage allows tube 40A to conduct each half cycle to energize relay winding 18. The condenser 120 connected in shunt with the relay winding 18 is generally for filtering purposes and serves to prevent chatter in the relay, which chatter might otherwise occur since the relay winding is energized from a source of one-half wave pulses. It is observed that since operation of the arrangement depends on the pulse height, i. e., amplitude of photo cell 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, pickup of a power frequency component in the photo cell 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; resistance 68 may have a magnitude of five to ten megohms and the tap thereon is preferably fixed, once it is adjusted; resistance 92 may be five megohms; resistance 102 may be 100,000 to 500,000 ohms; condenser 103 may be four to five microfarads; resistance 75 may be five megohms.

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 pickup, the pickup has the same effect on each pulse whereas the flame produces an amplitude or height variation in essentially each photo cell current pulse.

It is evident from the above that during the nonconducting half of the alternating current cycle the precharged condenser 72 establishes certain voltage conditions in the serial circuit which includes the resistances 68 and 69, the 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 more negative than the lower terminal of 69 in Figure 3, 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 cutoff. On each conductive half cycle a pulse is produced in the network which includes the cell 56, the winding 64 and resistance 68, such pulse producing a voltage across the resistance 68 which may be considered to represent the instantaneous intensity of the flame. In effect, such voltages representing respectively the average intensity and the instantaneous intensity are compared and the resultant is applied between the control grid and cathode of the tube 40 to cause the same to conduct only when the instantaneous intensity of the flame, during the conductive half cycle, 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 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 both the main burner as well as from the pilot burner simultaneously.

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, a 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 nonconducting, means connected between said cathode and said 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.

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-type resistance having a tap thereon connected to said control grid and having opposite terminals thereof serially connected with said cell and said third winding, said third winding being so poled that said cell conducts only when said device is rendered conductive by said first winding, a second and a third resistance serially connected 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, said third resistance having one of its terminals connected to one terminal of said third winding and connected also 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, said first, second and third transformer windings being energized from a common source.

3. In a flame detecting arrangement of the character described, a device having a cathode, a control grid and an anode, a first winding connected between said cathode and said anode, a second winding connected between said anode and said control grid and tending to render said control grid negative when said anode is rendered positive by said first winding, means connected between said control grid and said cathode for rendering said device conductive only when the intensity of the flame exceeds a predetermined average level and for thereafter rendering said device nonconducting when the flame intensity falls below said level.

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 render said control grid negative when said first winding renders said anode positive, a photoelectric cell, said third winding being serially connected with said photoelectric cell and poled to cause said cell to conduct only when said device is rendered conductive by said first winding, a first resistance, a second resistance serially connected 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 potentiometer resistance having its tap connected to said control grid and its terminals connected in a series circuit with said cell and said third winding.

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, 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 series circuit comprising 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-

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.

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