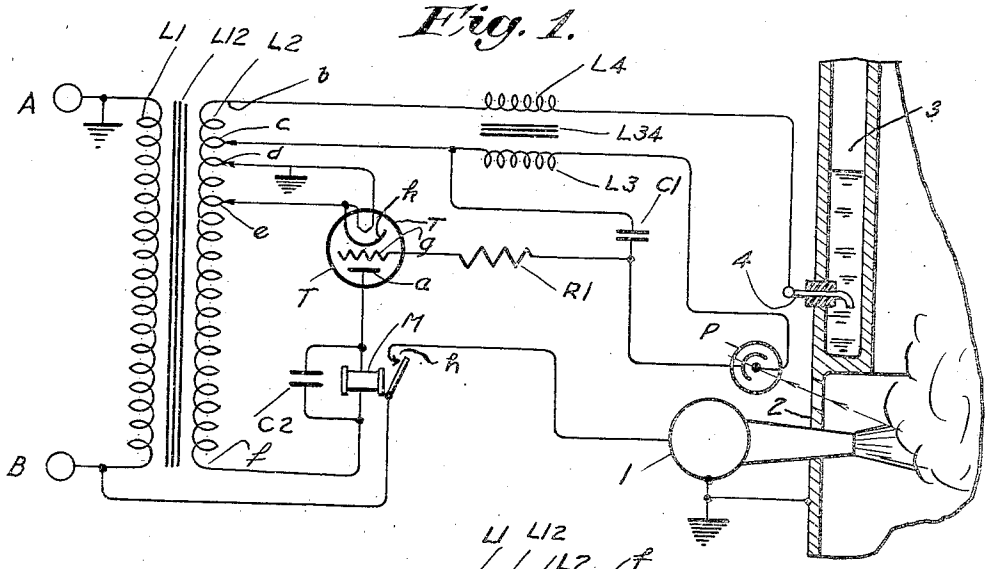
March 4, 1947. E. C. THOMSOM 2,416,781

FLAME FAILURE SAFEGUARD

Filed Oct. 9, 1945

Fig. 1.



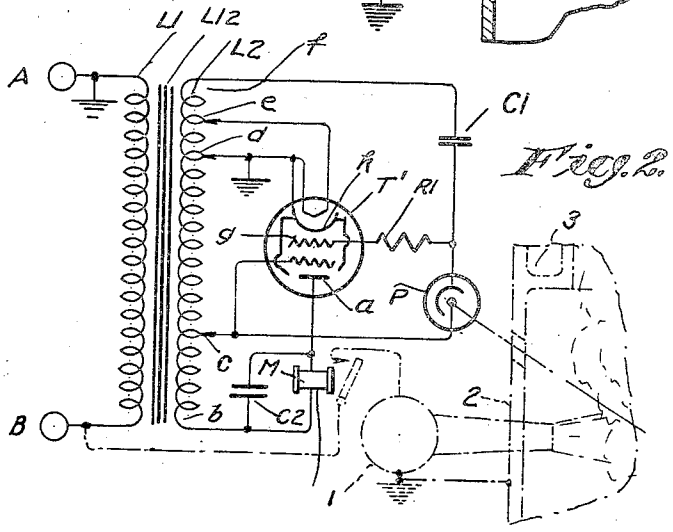


Fig. 2.

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FLAME FAILURE SAFEGUARD

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14 Claims. (Cl. 250—41.5)

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This invention relates to safety devices, and more particularly to devices used to detect flame failure in domestic or industrial heating plants. It has long been recognized that the failure of flame for any reason, such as momentary failure of the fuel supply or congestion in the fuel line, frequently results in an explosion if unignited fuel is allowed to enter the combustion chamber before the fire wall has cooled sufficiently. This hazard is particularly serious in an industrial heating plant burning a large volume of fuel.

Several types of controls have been in use in the past to detect flame failure and shut off the fuel supply. Most devices of this nature depend for their operation on the cooling of the combustion chamber after the flame has gone out, so that a considerable delay occurs before the fuel supply is shut off. During this period fuel may continue to enter the combustion chamber and therefore these devices have not eliminated the explosion hazard. Recently controls have been developed employing a phototube arranged so as to receive light from the flame. This type of control has the advantage that it operates immediately upon flame failure to shut off the burner. At present, however, devices of this type do not operate reliably under all the conditions normally encountered in heating installations. Many heating plants are shut down for several months out of the year. During this period the safety control may be subjected to extreme humidity. Under this condition the insulating materials ordinarily used for the base and socket of the phototube may absorb or become covered with moisture so that considerable leakage of current across the phototube base occurs when the control is again turned on. When the heating plant is in operation the phototube may be subjected to a high ambient temperature which accelerates the evaporation of the cathode material. This material becomes deposited on the inside of the tube envelope forming a conductive path between the anode and cathode leads and breaking down the internal resistance of the phototube. Under either of these conditions most controls of this type now used as flame failure safeguards become short circuited and allow unsafe operation of the heating plant.

In many installations, furthermore, it may be inconvenient or even impossible to add apparatus of appreciable size to the furnace wall in the proper position for obtaining an unobstructed light path from the phototube to the flame. In this case the phototube alone may be located on the furnace wall and the other components on a

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control panel at a considerable distance from the furnace. Under such conditions a certain amount of capacitance may be present between the phototube leads and it is essential that the performance of the safety control should not be adversely affected thereby.

While quick response of the safety control is essential, it is nevertheless usually desirable to introduce a small amount of delay to avoid premature operation on account of momentary variations or fluctuations in the flame.

The principal object of my invention is to provide a flame failure safeguard which gives satisfactory service and complete protection against explosion under any conditions likely to be encountered in a heating plant installation.

Another object is to provide a control which operates satisfactorily even though a moderate amount of leakage may be present, either internally through the phototube itself or externally through the base or socket, or between the wires of the cable connecting the phototube to the remainder of the circuit.

Another object is to provide a control of this type which shuts down the fuel pump or other controlling means of the heating plant when the phototube has deteriorated to a certain point and prevents operation of the heating plant until the tube has been replaced.

Another object is to provide a control which operates satisfactorily when the phototube is located at some distance from other components of the circuit.

Another object is to provide a control which is insensitive to momentary variations in the intensity of the flame.

Another object is to provide a control which gives considerable amplification of the controlling signal with the use of a minimum number of tubes and other components.

Another object is to provide a control which can be readily arranged to act in conjunction with other safety controls on the heating plant.

These and other objects, advantages, and features of my invention will be more fully apparent from an inspection of the drawings together with the following description of several embodiments thereof.

In the drawings illustrating the preferred embodiment of my invention:

Fig. 1 is a diagrammatic representation of the circuit as used in a heating installation in conjunction with a probe to detect an unsafe water level in a boiler, a portion of which is shown in cross-section; and

Fig. 2 is an alternative arrangement of the circuit without the probe, the dot-and-dash lines indicating boiler and burner equipment shown in Fig. 1.

Referring more in detail to the drawings and specifically to Fig. 1, L1 is the primary of a transformer 112 having secondary L2 with taps *b, c, d, e* and *f*. L1 is supplied with alternating current from terminals A and B. M is a relay of conventional type with one normally open contact *h* controlling the circuit of burner motor 1, and a smoothing capacitor C2 connected in parallel with the energizing coil thereof. 1 indicates a burner of any conventional type suitable for oil, pulverized coal, or other common fuel. T is a triode tube having a cathode *k* and an anode *a* and control grid *g*. P is a photocell arranged so that light from the flame falls on its cathode through a suitable opening in fire wall 2. 4 is an electrode having a central conductor separated by insulating material from the wall of a boiler 3. A transformer L34 has its primary winding L4 energized by alternating current from the section of secondary L2 between points *b* and *d*, the circuit being completed through the electrode 4, water in the boiler 3, and suitable ground connections at the boiler and point *d*. The secondary winding L3 applies an energizing voltage across the photocell P through a capacitor C1. The control grid *g* is connected to a point between the capacitor C1 and photocell P through a current limiting resistor R1. Thus the capacitor C1 is also connected between point *c* and control grid *g*.

The operation of the device is as follows. Assuming that point *b* of transformer secondary L2 is positive, point *c* is at a higher positive potential than point *e*. Grid *g* is therefore positive with respect to cathode *k* and grid current will flow by way of condenser C1 or phototube P.

Secondary L3 of transformer L34 may be of the same phase as primary L4 or of opposite phase. If L3 is of the opposite phase, P has its anode positive with respect to its cathode on this half cycle. If light falls on phototube P, lowering its impedance, the grid current flows through the phototube so that no charge is built up on condenser C1. During the half cycle when point *b* is negative, anode *a* of tube T is positive with respect to the cathode. The voltages on the taps are such that at this time, the negative bias of grid *g* derived from taps *c* and *e* is less than the cut-off potential of the tube so that if no charge is present on C1, tube T is conductive and relay M becomes energized. If no light falls on the phototube during the first half cycle, condenser C1 becomes charged by grid current. The charge on C1 combined with the bias supplied by taps *c* and *e*, holds the grid negative during the next half cycle so that tube T becomes nonconductive and relay M deenergized. The number of cycles required for capacitor C1 to acquire sufficient charge to render tube T nonconductive on the next succeeding conductive half cycle depends upon the size of the capacitor, among other factors. A larger capacitor will require a greater number of cycles, hence a longer time, to acquire the required negative charge. Contact *h* is then opened shutting down the burner. Likewise, if the level of water in boiler 3 falls below probe 4 the circuit through primary L4 is open and no voltage is applied across the phototube so that C1 retains its charge and tube T becomes nonconductive and relay M deenergized.

If secondary L3 is of the same phase as primary L4, the phototube is nonconductive during the period when C1 is being charged by grid current. During the next half cycle, however, condenser C1 may discharge through the phototube if light is present so that tube T becomes conductive as before. If no light falls on the phototube, or the circuit through primary L4 is open, condenser C1 retains its charge and tube T becomes nonconductive. The action of the control is, therefore, the same regardless of the phasing of the transformer. Obviously a thermostat located in a space to be heated by the system shown in Fig. 1 may be substituted for or provided in addition to the electrode 4 and water for controlling the circuit of the primary L4 of transformer L34, and hence energization of the burner 1.

When phototube P becomes dark after being illuminated for some time or when the water level sinks below probe 4, it is evident that, depending on the sizes of condenser C1 and resistor R1, several cycles may be required to build up sufficient charge on the condenser to bring the grid of tube T to cut-off potential. A certain amount of delay, therefore, may occur in the response of the control. This delay may be adjusted to any desired value by appropriate choice of the sizes of the various elements.

Referring now to Fig. 2, T' is preferably a tetrode of the beam-power type used in this case to obtain maximum sensitivity in the control. T' may be replaced by a triode without altering the function of the circuit, otherwise than to reduce the power delivered to the relay for a given strength of light signal. The anode *a* is connected to point *b* through the relay M, and the cathode *k* is connected to point *d*, which may be grounded. Heater power is supplied by that portion of the secondary L2 between the points *d* and *e*. The charging capacitor C1 and photocell P are series connected between points *c* and *f*, and the control grid is connected to the junction between them through the limiting resistor R1. The screen grid is connected to point *c*, with the anode of the photocell P. When point *b* is negative, grid *g* is positive with respect to cathode *k* and grid current flows charging condenser C1. On the next half cycle, if phototube P is illuminated, condenser C1 may be discharged through the phototube so that grid *g* remains above the cut-off potential as explained in the reference to Fig. 1. If phototube P is dark, the charge accumulates on condenser C1 until the voltage of grid *g* becomes sufficiently negative to prevent flow of current through the tube and relay M becomes deenergized.

The effect of leakage across the phototube may be demonstrated by considering a resistance in parallel with phototube P. If this resistance is large, compared with the reactance of condenser C1, as is the case under normal operating conditions, the alternating voltage developed across C1, due to the leakage current through this resistance, will be negligible. For small values of the leakage resistance, the discharge path provided thereby for condenser C1 will be such that the grid current will not be sufficient to maintain the proper charge on C1. A leakage of this magnitude, however, would not ordinarily be caused by humidity and the phototube would fail because of destruction of the cathode surface before internal leakage occurred to this extent. In either of these cases, leakage through a relatively low impedance path, or phototube failure,

the tube T or T' is rendered nonconductive, and the burner I is deenergized.

If the phototube is located at some distance from tube T or T', the interconnecting cable will place considerable capacity in shunt with phototube P. This capacity will similarly introduce a small alternating current in condenser C1, but if its value is small as compared with C1, again the alternating voltage generated across C1 is negligible, and the D. C. voltage across C1 will be substantially unchanged. If a time delay is desired, or may be tolerated, so that C1 may be made large, the phototube may be located at extremely long distances from the circuit without affecting its operation.

The average charge on condenser C1 thus depends only on the rectification property of the phototube, and is independent of leakage currents in the phototube circuit over a wide range.

The phototube used in these circuits may be of any conventional type either vacuum or gas filled. A particular advantage is gained by the use of the gas filled type. The derivation of the phototube potential from an independent supply rather than from the grid and cathode tap allows sufficient potential to be applied to the phototube to cause slight ionization of the gas by photoelectrons regardless of the characteristics of the amplifier tube used. As is well known in the art, the amplification thus obtained gives rise to a phototube current of several times that normally obtained from a vacuum phototube under the same conditions. High sensitivity is thus obtained with a minimum of stages of amplification.

Since certain changes may be made in the above-described article and different embodiments of the invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative only and not in a limiting sense.

I claim:

1. In electronic control apparatus having an alternating current source; an electron discharge device having an anode, cathode, and control electrode; a capacitance connected between a first point on said source and said control electrode; a rectifying impedance connected between said control electrode and a point on said source; a connection from said cathode to a second point on said source, and a connection from said anode to a third point on said source, said second point being between said first and third points; the potential difference between said first and second points being less than that required between said cathode and said control electrode to block the flow of current through said discharge device.

2. In electronic control apparatus having an alternating current source; an electron discharge device having an anode, cathode, and control electrode; a capacitance connected between a first point on said source and said control electrode; a photoelectric device connected between said control electrode and a point on said source; a connection from said cathode to a second point on said source, and a connection from said anode to a third point on said source, said second point being between said first and third points; the potential difference between said first and second points being less than that required between said cathode and said control electrode to block the flow of current through said discharge device.

3. In electronic control apparatus having an alternating current source; an electron discharge device having an anode, cathode, and control electrode; a rectifying impedance connected between a first point on said source and said control electrode, the connection including variable impedance means; a capacitance connected between said point and said control electrode; a connection from said cathode to a second point on said source, and a connection from said anode to a third point on said source, said second point being between said first and third points; the potential difference between said first and second points being less than that required between said cathode and said control electrode to block the flow of current through said discharge device.

4. In electronic control apparatus having an alternating current source; an electron discharge device having an anode, cathode, and control electrode; a photoelectric device connected between a first point on said source and said control electrode, the connection including variable impedance means; a capacitance connected between said point and said control electrode; a connection from said cathode to a second point on said source, and a connection from said anode to a third point on said source, said second point being between said first and third points; the potential difference between said first and second points being less than that required between said cathode and said control electrode to block the flow of current through said discharge device.

5. In electronic control apparatus having an alternating current source; an electron discharge device having an anode, cathode, and control electrode; transformer means having a primary and secondary; a rectifying impedance connected between said control electrode and a first point on said source; said connection including said secondary; a capacitance connected between said control electrode and said first point; a connection from said cathode to a second point on said source and a connection from said anode to a third point on said source, said second point being between said first and third points; connections, including a detecting impedance, for energizing said primary from said source; the potential difference between said first and second points being less than that required between said cathode and said control electrode to block the flow of current through said discharge device.

6. In electronic control apparatus having an alternating current source; an electron discharge device having an anode, cathode, and control electrode; transformer means having a primary and secondary; a photoelectric device connected between said control electrode and a first point on said source; said connection including said secondary; a capacitance connected between said control electrode and said first point; a connection from said cathode to a second point on said source and a connection from said anode to a third point on said source, said second point being between said first and third points; connections, including a detecting impedance, for energizing said primary from said source, the potential difference between said first and second points being less than that required between said cathode and said control electrode to block the flow of current through said discharge device.

7. In electronic control apparatus having an alternating current source; an electron discharge device having an anode, cathode, and control electrode; a capacitance connected between a first point on said source and said control electrode; a rectifying impedance connected between said control electrode and a second point on said

source; a connection from said cathode to a third point on said source, and a connection from said anode to a fourth point on said source; said second and third points being between said first and fourth points; the potential of said first point with respect to said third point being opposite in phase from the potential of said second point with respect to said third point.

8. In electronic control apparatus having an alternating current source; an electron discharge device having an anode, cathode, and control electrode; a capacitance connected between a first point on said source and said control electrode; a photoelectric device connected between said control electrode and a second point on said source; a connection from said cathode to a third point on said source, and a connection from said anode to a fourth point on said source; said second and third points being between said first and fourth points; the potential of said first point with respect to said third point being opposite in phase from the potential of said second point with respect to said third point.

9. In electronic control apparatus having an alternating current source; an electron discharge device having an anode, cathode, and control electrode; transformer means having a primary and secondary; a rectifying impedance connected between said control electrode and a first point on said source; said connection including said secondary; a capacitance connected between said control electrode and said first point; a connection from said cathode to a second point on said source; a connection from said anode to a third point on said source; and connections, including a detecting impedance, from said primary to fourth and fifth points on said source, said third and fifth points being substantially the end terminals of said source.

10. In combination a discharge device having an anode, cathode, and control electrode, and means for energizing the anode-cathode circuit thereof; a network, including a rectifying impedance, adapted to control the potential of said control electrode, the effect of said network on said control electrode being substantially unchanged when said rectifying impedance is bridged in parallel by a nonrectifying impedance of greater than a predetermined value.

11. In combination a discharge device having an anode, cathode, and control electrode, and means for energizing the anode-cathode circuit thereof; a network, including a light-sensitive device, adapted to control the potential of said control electrode, the effect of said network on said control electrode being substantially unchanged when said light-sensitive device is bridged in parallel by a nonrectifying impedance of greater than a predetermined value.

12. In combination a discharge device having an anode, cathode, and control electrode, and means for energizing the anode-cathode circuit thereof; a network, including in series a rectifying impedance and capacitance inductively coupled to a detecting impedance, said network being adapted to control the potential of said control electrode and the effect of said network on said control electrode being substantially unchanged when said rectifying impedance is bridged in parallel by a nonrectifying impedance of greater than a predetermined value.

13. Apparatus for supervising a flame having electrically operable means for supplying fuel thereto comprising: in combination; a source of power and an electron tube having an anode, a cathode, a control grid and a screen grid, said anode being connected to one end of said source, said cathode being connected to a first point on said source near the other end thereof, said control grid being connected to said other end through a series-connected resistor and capacitor, said screen grid being connected to a second point on said source near the anode end thereof; a phototube having its cathode connected to a point between said resistor and capacitor and its anode connected to said second point; and means in the connection between said anode and said source for controlling the operation of said fuel supplying means; said tube being adapted to become conductive when said anode end of said source is positive with relation to said other end, the portion of said source between said other end and said first point at that time providing to said control grid a potential that is negative with respect to the cathode potential, but not sufficiently negative to cut off said tube; said capacitor being charged negatively on the side nearest said control grid by grid current through said resistor when said other end of said source is positive with relation to said anode end, the voltage on said capacitor being added to said negative grid potential and adapted to cut off said tube when said voltage reaches a predetermined value; said phototube when illuminated by said flame, providing a discharge path for the negative charge accumulated on said capacitor during the times when the anode end of said source is positive with relation to said other end, but providing no discharge path when not illuminated.

14. In a system for heating a liquid in a container and having electrically operable means for supplying fuel to the heating flame, apparatus for simultaneously supervising said flame and the level of said liquid in said container comprising, in combination: a source of alternating voltage having first and second end terminals and first and second intermediate taps thereon running from said first to said second end; an electron discharge tube having at least an anode, a cathode, and a control electrode; said cathode being connected to said second tap and said anode to said second end terminal, and current responsive relay means in the anode-cathode circuit; a circuit for energizing said fuel supplying means, and a switch in said circuit operable to a closed-circuit condition by said relay means when a sufficiently great current flows in said anode-cathode circuit; a capacitor connected at one end to said first tap and at the opposite end to said control electrode, said capacitor being adapted to accumulate electrons to provide a negative charge on its control electrode side during the alternating current half-cycles when said tube would be normally nonconductive, said charge, upon reaching a predetermined value being adapted to reduce the conductivity of said tube during the normally conductive half cycles below that required to maintain said switch in said closed-circuit condition; a transformer having a primary winding and a secondary winding said primary winding being energized from said source, the energizing circuit including in series connection with said primary winding said first and terminal and a supervising electrode immersed in said liquid at a predetermined height in said container, said energizing circuit being broken when said level falls below said height; a photocell and said secondary winding connected in series across said capacitor, the photocell cathode being connected to said control electrode, said

photocell being arranged for illumination by said flame, and being furnished with energizing voltage by said secondary winding, said photocell when illuminated by said flame and energized being adapted to remove electrons from said control electrode side of said capacitor and prevent the accumulation of said negative charge; whereby, when said level is at least at said height and said flame exists, said switch is mantained in closed-circuit condition, but if either said level falls below said height, or said flame ceases to exist electrons are accumulated on said control electrode side of said capacitor and said switch is operated to an open-circuit condition.

E. CRAIG THOMSON.

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Disclaimer

2,416,781.—*Elihu Craig Thomson*, Boston, Mass. FLAME FAILURE SAFEGUARD. Patent dated Mar. 4, 1947. Disclaimer filed Oct. 23, 1947, by the assignee, *Combustion Control Corporation*.

Hereby enters this disclaimer to claims 1, 2, 10, and 11 in said specification.

[*Official Gazette December 2, 1947.*]

Certificate of Correction

Patent No. 2,416,781. March 4, 1947.

ELIHU CRAIG THOMSON

It is hereby certified that error appears in the above numbered patent requiring correction as follows: In the heading to the drawing, line 1, for "E. C. THOMSOM" read *E. C. THOMSON*; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 26th day of October, A. D. 1948.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.