July 20, 1948. T. J. MESH 2,445,531

SAFETY CONTROL SYSTEM FOR BURNERS

Filed April 16, 1945 5 Sheets-Sheet 1

Fig. 1.

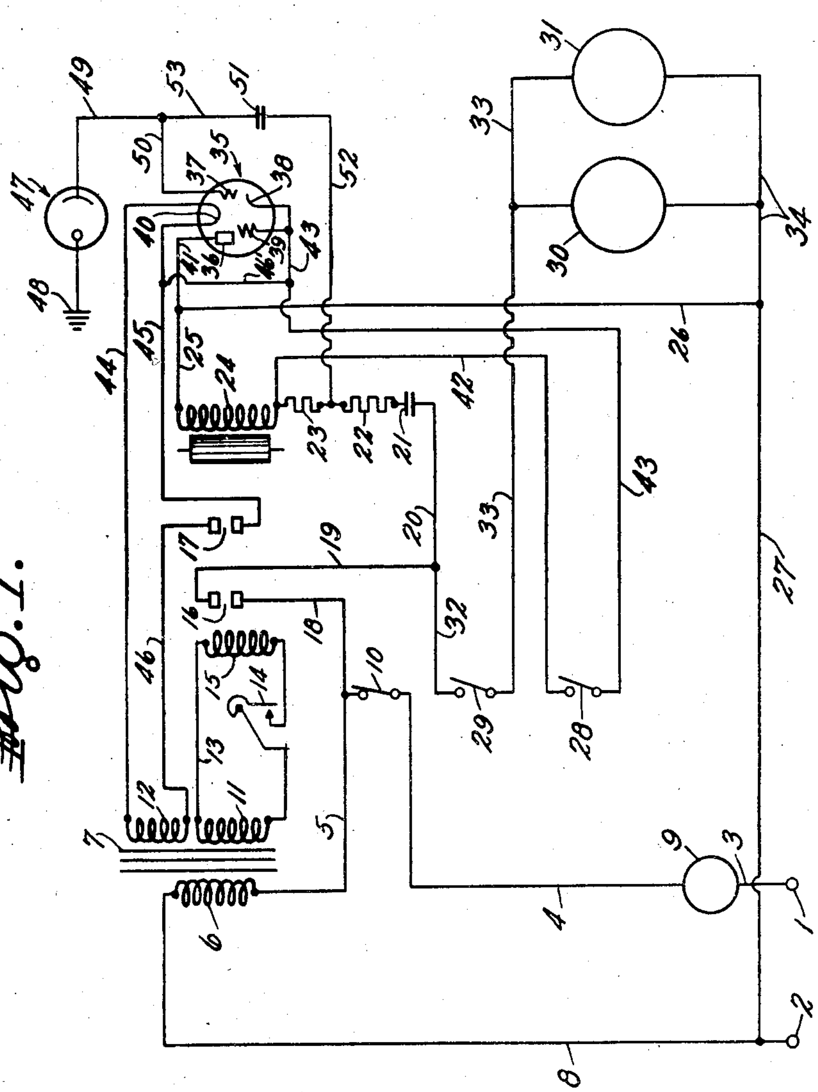

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Fig. 4.

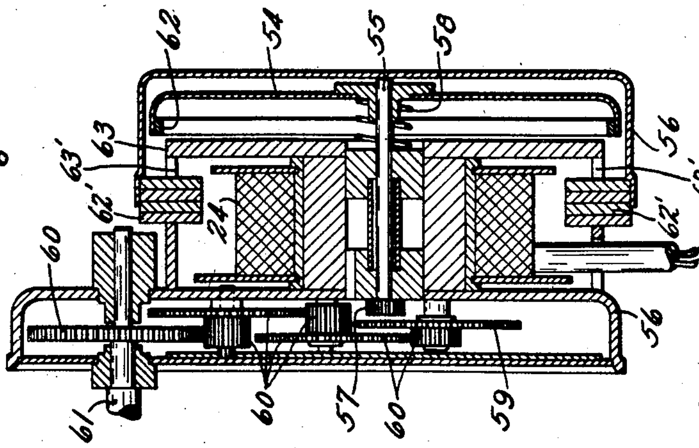


Fig. 2.

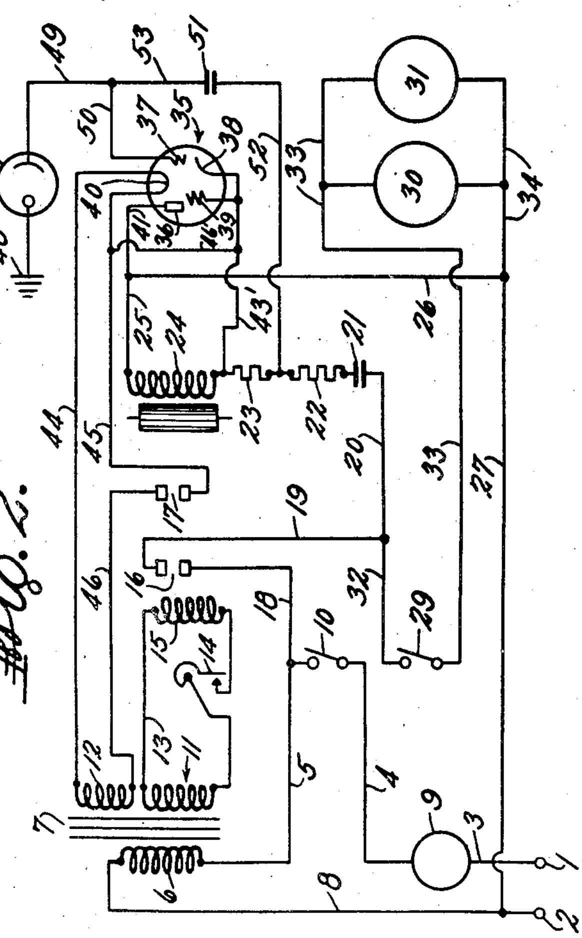
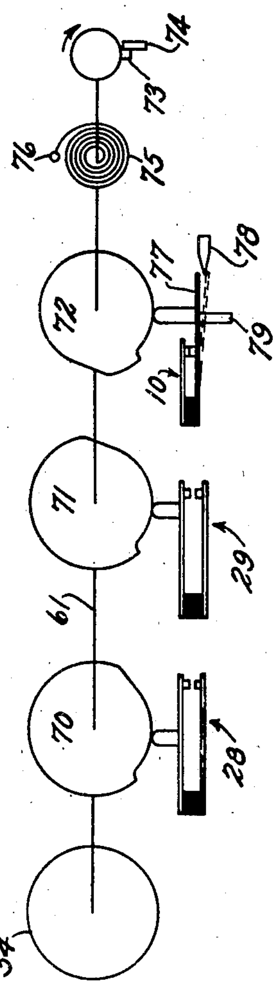


Fig. 5.



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SAFETY CONTROL SYSTEM FOR BURNERS

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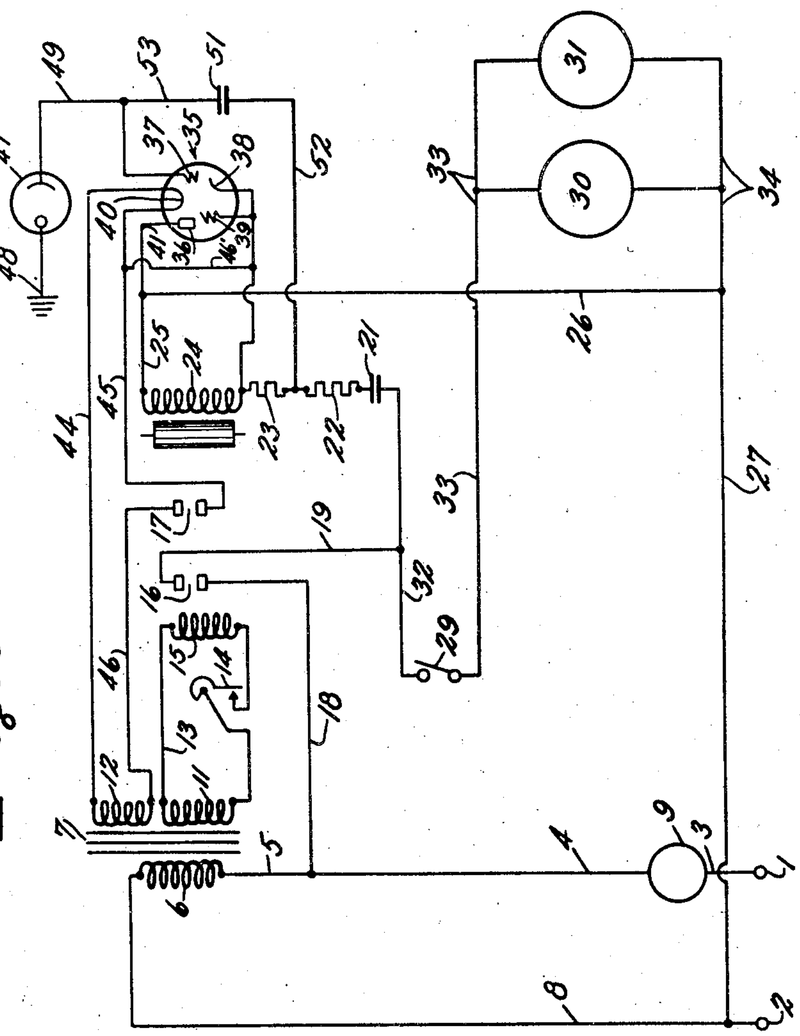

Fig. 3.

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Fig. 6.

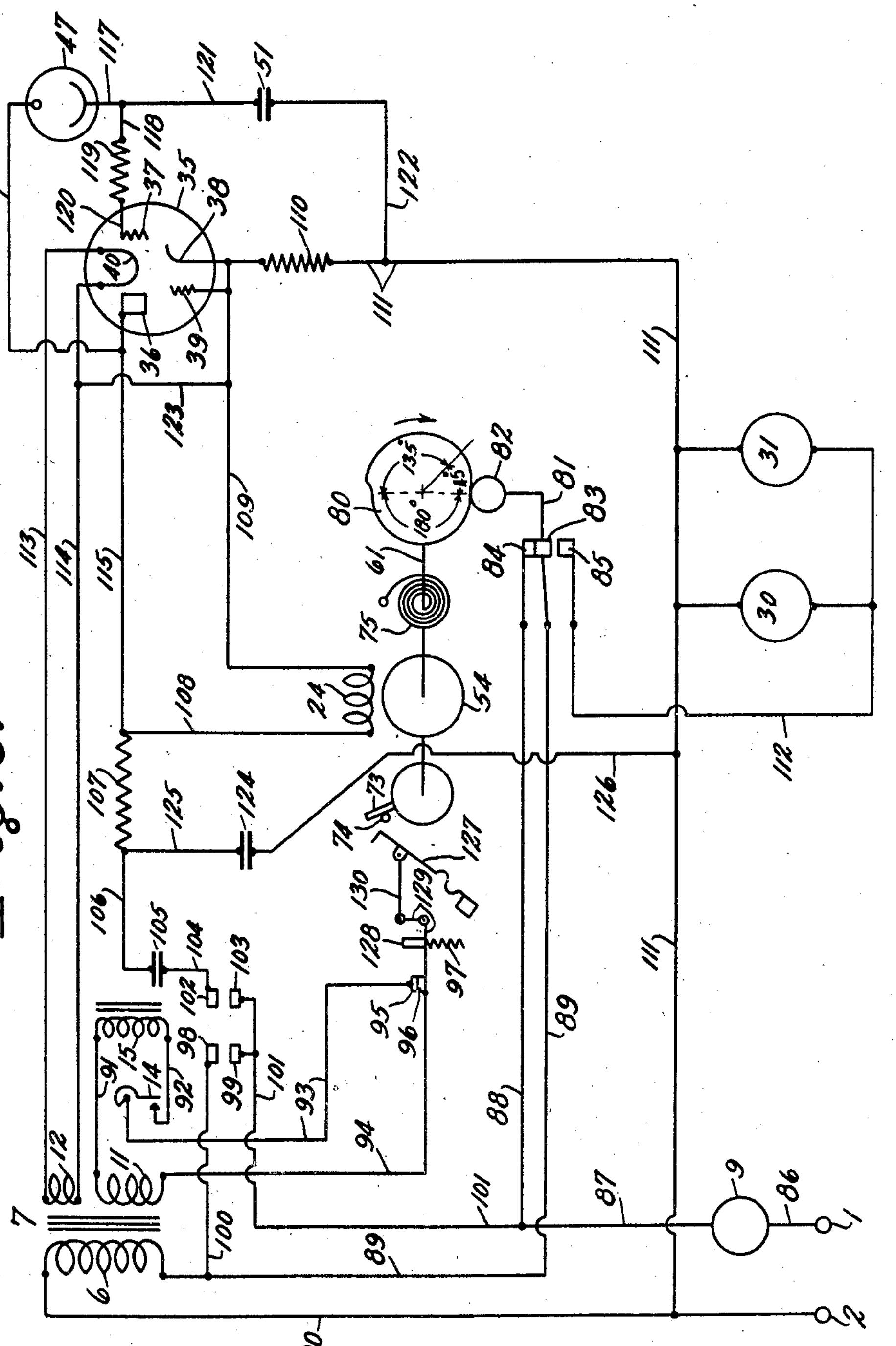

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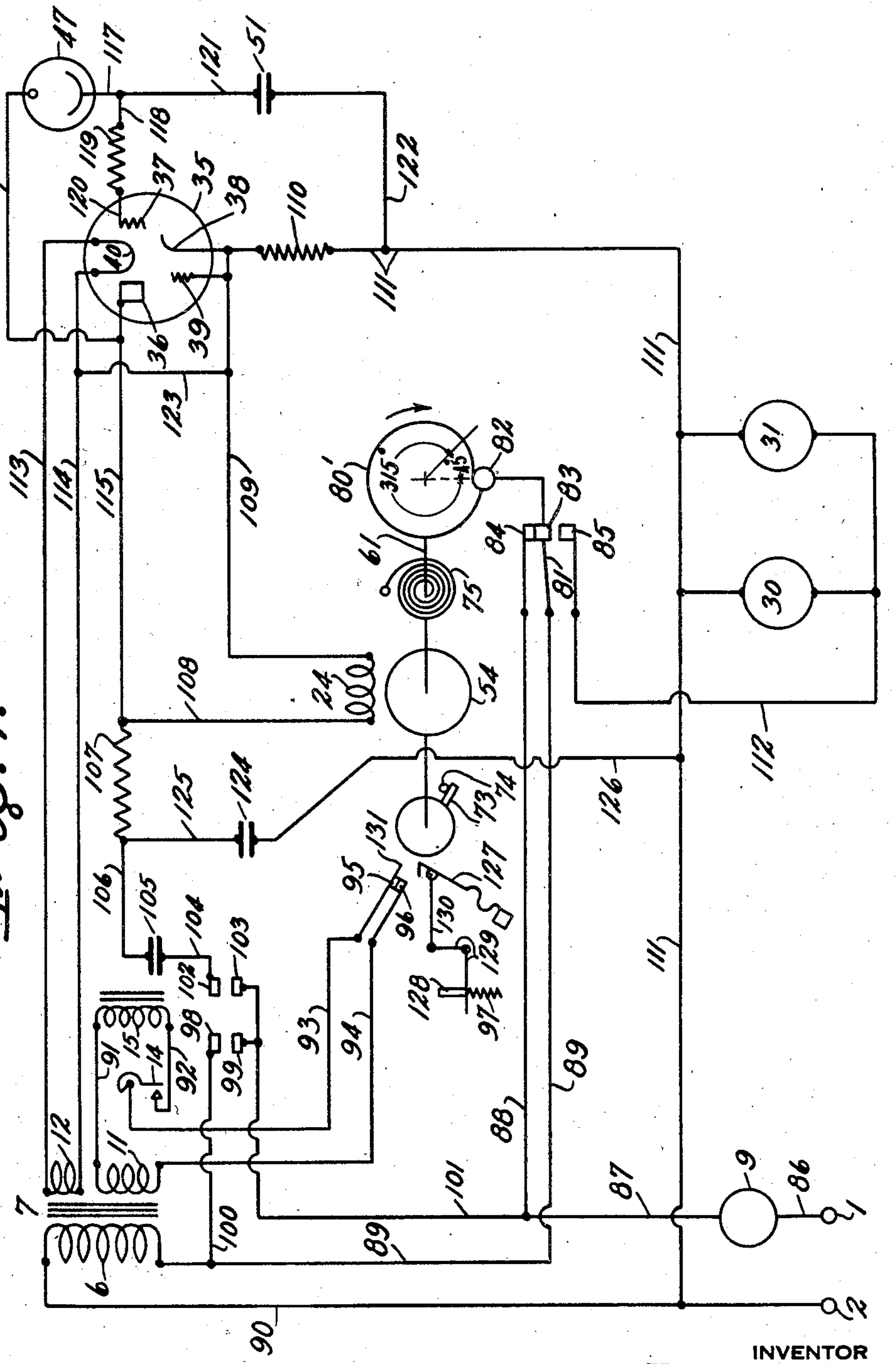
Fig. 7.



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Patented July 20, 1948

2,445,531

UNITED STATES PATENT OFFICE

2,445,531

SAFETY CONTROL SYSTEM FOR BURNERS

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Application April 16, 1945, Serial No. 588,451

16 Claims. (Cl. 158—28)

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This invention relates to improvement in control systems for burners, such for example as those using liquid or gaseous fuel.

This application is a continuation in part of my application Serial No. 542,841, filed June 30, 1944, and which has become abandoned.

The invention has for its general objects to provide an improved burner control system which is relatively simple, can be produced at relatively low cost, requires little servicing, is reliable in operation and is exceedingly compact.

The invention makes use of a well known form of control motor for actuating the switch or switches of the system. A small, alternating current, synchronous motor, set into action on a call for heat by a thermostat switch, drives, through gear reduction mechanism, including an electromagnetically-operated clutch, a timing shaft having thereon means for actuating the switch or switches of the system at a predetermined time or times after the control motor is started. The timing shaft is turned in one direction only by the control motor and, when so turned, winds up a spring which is later used to return the shaft to its initial position, when the clutch is released by deenergization of its electromagnetic-operating means on opening of the control motor circuit, to interrupt the transmission between the shaft and the control motor.

The invention has for one object to provide means operable with a very small amount of power for stopping the control motor substantially instantaneously, when combustion occurs at the burner following the starting of the burner by a switch actuated by the timing shaft, and for magnetically holding the motor and its timing shaft in its stopped position with the clutch engaged—a failure of combustion allowing the shaft to move beyond said position and stop the burner.

The invention has for another object to provide electronic means, set into action by any suitable means responsive to the occurrence of combustion in the burner, for effecting the stopping of the control motor and the magnetic holding of it in the aforesaid position without the use of switches or relays and without opening the circuit of the control motor.

The invention has for a further object to provide, as a control element for said electronic means, a phototube located to respond to the presence of flame at the burner and adapted to set said means into action.

The invention has for another object to provide a grid-controlled vacuum or gaseous-discharge rectifier tube having its plate-cathode circuit con-

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nected directly across the terminals of the field winding of the control motor and set into action by a suitable combustion responsive control, whereby to rectify the alternating current and produce a pulsating direct current in a short circuit across said winding for the purpose of stopping the motor and magnetically holding it in its stopped position.

The invention has for another object the provision in a control system of the class described of means for preventing resetting of the timing shaft by its spring, whenever the burner is stopped by the safety means because of failure of combustion, for the purpose of preventing recycling of the control unless and until the preventing means is manually released.

The invention has for another object the provision in a control system of the class described, of means for compelling resetting of the timing shaft to its initial position as a condition precedent to a subsequent cycle of operation of the shaft, for the purpose of providing a safe failure of the control in case the timing shaft fails to reset because of a broken reset spring, or sticking of the timing shaft or motor in "on" position or for any other reason.

The invention will be disclosed for illustrative purposes in connection with the accompanying drawings, in which,

Fig. 1 is a diagrammatical view of a burner control system embodying the invention;

Figs. 2 and 3 are diagrammatical views showing modifications of the control system;

Fig. 4 is a sectional view of the control motor, its timing shaft, gear reduction mechanism, and clutch;

Fig. 5 is a diagrammatical view of the control motor, timing shaft and the switches actuated thereby; and

Figs. 6 and 7 are diagrammatical views showing other modifications of the control system.

Referring to Fig. 1, 1 and 2 are the hot and ground terminals of a 115 volt, 60 cycle, alternating current supply. The terminal 1 is connected by wires 3, 4 and 5 to one terminal of the primary 6 of a step down transformer 7. The other terminal of the primary 6 is connected by a wire 8 to the terminal 2. Interposed between wires 3 and 4 is a normally-closed limit control switch 9, such for example as a switch opening in response to excess pressure of steam in the boiler, being heated by the burner. Interposed between the wires 4 and 5 is a safety lockout switch 10, which is normally closed but can be opened automatically on failure of combustion, as will later appear. Under normal conditions, the primary circuit of transformer 7 is closed.

This transformer has two secondary windings—one, marked 11, supplying current at 24 volts for example, and the other marked 12, supplying current at 6 volts for example. The 24 volt winding is in a circuit 13 including in series a room thermostat switch 14 and the coil 15 of a relay, having two sets of mating contacts 16 and 17, respectively, the contacts of each set engaging when coil 15 is energized.

One of the contacts 16 is connected by a wire 18 to switch 10 and through the latter, wire 4, limit switch 9 and wire 3 to one terminal 1 of the alternating current supply. The other of contact 16 is connected by wires 19 and 20 to a capacitor 21 and through the latter and resistors 22 and 23 to one terminal of the main field winding 24 of a control motor such for example as a self-starting synchronous electric motor. The other terminal of this field winding is connected by wires 25, 26 and 27 to the ground terminal 2 of the alternating current supply. Thus, on closure of the thermostat switch 14, the relay will be energized and contacts 16 closed to start the control or timing motor.

This motor actuates three switches in sequence. They are, in the order of their actuation—a switch 28, which is initially open and is closed by operation of the timing motor a predetermined time after the motor is started; a switch 29 which is initially open and is closed by operation of the timing motor a predetermined time after switch 28 is closed; and the described switch 10, which is initially closed and is opened if and when the timing motor continues in operation a predetermined time after the closing of switch 29.

The switch 29 controls the burner motor 30 and the ignition means 31, setting them into operation on closure of the switch, current flowing through wire 3, limit switch 9, wire 4, switch 10, wire 18, contacts 16, wire 19, a wire 32, switch 29, a wire 33 to the motor 30 and ignition means 31 and thence by a wire 34 and wire 27 to supply terminal 2.

The switch 28 connects a rectifying means across the field winding 24 of the timing motor. The purpose of this means is to stop the timing motor, if combustion occurs before the motor moves far enough to open switch 10. The rectifying means as herein shown, is electronic. Preferably, such means consists of a grid-controlled, gaseous-discharge rectifier tube 35, such as a thyratron, having a plate 36, grid 37, cathode 38, shielding grid 39 and a tube heater 40. The plate-cathode circuit of this tube is suitably coupled to the field 24 of the timing motor. As shown, the plate 36 is connected by a wire 41 to wire 25 and thus to one terminal of the field winding 24. The other terminal of winding 24 is connected by a wire 42 to one terminal of switch 28 and the other terminal of switch 28 is connected by a wire 43 to the cathode 38. The shielding grid 39 is also connected to wire 43.

The tube heater 40 is connected by wires 44, 45 and 46 in a series circuit with the secondary 12 of the transformer and with the contacts 17. Thus, on a call for heat when thermostat switch 14 closes, the contacts 17 are engaged and the heater is supplied with low voltage current. The heating of the tube and the operation of the timing motor are initiated simultaneously. One terminal of the tube heater is connected to the shielding grid 39 and cathode 38 as by a wire 46′ which interconnects wires 43 and 45.

The electronic tube 35 is set into action by means of a suitable combustion control when combustion occurs. A desirable form of combustion control is a phototube 47. One terminal of this tube 47 is grounded as at 48 and thus connected to wire 2. The other terminal is connected by wires 49 and 50 to grid 37. The tube 47 is thus connected across the plate 36 and grid 37 of the electronic tube 35. Thus, wires 49 and 50 connect one terminal of tube 47 to grid 37 and the plate 36 is connected to ground terminal 2 by wires 41, 26 and 27 and thus to the grounded terminal 48 of the tube 47. The phototube 47 is so located as to respond to the presence of flame in the combustion chamber of the burner. When combustion occurs the electronic tube is set into action.

Bias for the grid of tube 35 is provided by the voltage drop across the resistor 23, which drop may, for example, be 6.75 volts. This bias is applied to the grid through a capacitor 51 of from .0002 to .004 microfarad capacity. A wire 52 connects one terminal of this capacitor to a point between the resistors 22 and 23. A wire 53 connects the other terminal of the capacitor 51 to wire 50 and thus to grid 37.

When the electronic tube 35 is set in action by the phototube 47 in response to the presence of flame or by any other suitable combustion-responsive means, a pulsating direct current flows through wires 41, 25 and 43 of such magnitude as to produce for all practical purposes the effect of a short circuit across the motor field 24 on the positive half cycles of voltage. Impedance is included in the circuit with the motor field, first for the purpose of limiting the current flow in the rectifier during the aforesaid short circuit periods and, second, for the purpose of dropping the motor voltage across the motor field 24 to a very low value when rectified current flows through the wires 41, 25 and 43. The resultant effect is the elimination from the field 24 of the major portion of the positive half cycles of the voltage wave and the timing motor stops instantly and is held magnetically against movement as long as rectified current flows through the wires 41, 25 and 43.

It will be noted that the impedance which is in series circuit with the timing motor is composed of the capacitor 21, which may for example have a capacity of 1 microfarad, and the resistors 22 and 23, which may for example respectively be of 500 and 150 ohms resistance. The circuit of the timing motor is in partial resonance with the result that the arithmetical sum of the voltages across the motor, capacior and resistors is more than the applied line voltage of 115. The vector sum of these voltages is nevertheless 115. This provides a convenient method of obtaining full motor voltage, without the use of a transformer, and at the same time securing a good series impedance to limit the current in tube 35, when it is actuated. These resistors are chosen to give exactly the rated voltage at the timing motor using the most nearly correct, commercially available size of capacitor (1.0 microfarad). If exactly the right size of capacitor were available the resistor 22 could be dispensed with. The resistors also keep the peak plate current in tube 35 well below the rated value and thus make for long tube life. Capacitor 21 voltage is about 120; motor voltage, 110; resistor 21, 6.75 volts; and resistor 23, about 22.5 volts, assuming line voltage to be 115. The timing motor is rated at 110 volts and normally draws 3.6 watts from the line.

The timing motor is shown in section in Fig. 4. Its rotor 54 is fixed to one end of a shaft 55, which is rotatably mounted in bearings in the casing 56 and which has fixed to its other end a pinion 57. This shaft is axially movable. A spring 58 moves it to the right into, and yieldingly holds it in, the illustrated position, in which the pinion 57 is out of mesh with a gear 59 of a gear reduction mechanism. The latter comprises the pinion 57, the gear 59 and a train of gears 60, which are mounted in casing 56 and drive a timing shaft 61. When the field 24 of the timing motor is energized, the rotor 54 is drawn by magnetic attraction to the left until the magnetic ring 62 of the rotor comes into line with the pole piece member 63. As a result, the pinion 57 will be moved into mesh with gear 59 and, as the rotor rotates, the shaft 61 is turned at a definite time rate, say for example, one revolution per minute. The pinion 57 and gear 59 constitute a clutch operable by electromagnetic means comprising the field 24 and armature 54 of the timing motor. The details of the motor construction are not important to the present invention and description of them is deemed unnecessary. The motor construction may, for example, be substantially the same as is shown in the Haydon Patent No. 1,996,375, dated April 2, 1935, to which reference is made for a more complete disclosure of the motor if such is necessary or desired. As more fully disclosed in said patent, a shaded pole winding, comprising short circuited copper rings 62′ surrounding the polar projections 63′, is used for starting purposes.

The timing shaft 61, and the switch-actuating means thereon, are shown in diagrammatical form in Fig. 5. This shaft, as shown, carries three cams 70, 71 and 72 for actuating the switches 28, 29 and 10, respectively. The shaft 61 can be turned in a clockwise direction by the timing motor until a stop 73, movable with the shaft, engages the right hand side of a fixed abutment 74. A spring 75, connected at one end to the shaft and at the other end to a stationary member 76, is adapted to be wound up by the clockwise rotation of the shaft. Then, when the motor field 24 is deenergized, the magnetic pull on rotor 54 is broken and spring 58 moves it into the position illustrated in Fig. 4, disengaging pinion 57 from gear 59, whereupon the spring 75 will turn shaft 61 in a counterclockwise direction back into the illustrated position, wherein the stop 73 abuts the left hand side of abutment 74.

In the particular example shown in Fig. 5, the shaft 61 turns clockwise at the rate of one revolution a minute or 6 degrees in one second. In the zero and rest position shown, the cam followers of all three switches are engaged with the low dwell portions of their respective cams, whereby the switches 28 and 29 are open and switch 10 is closed. Cam 70 starts its rise in 7 seconds and completes it in 12 seconds, whereupon switch 28 will be closed. The plate-cathode circuit to the field of the timing motor 24 is thus established. This switch 28 will be maintained closed by the engagement of its follower with the high dwell portion of cam 70, until the shaft reaches the end of its clockwise travel or until stop 73 abuts the right hand side of abutment 74, when the follower rides off onto the low dwell portion of the cam and the switch 28 opens. Cam 71 starts its rise in 12 seconds from zero position and completes it in 17 seconds, whereupon switch 29 is closed to start the burner motor 30 and the ignition means 31. This switch 29 is maintained closed by the high dwell portion of cam 71 until the shaft 61 completes its clockwise travel, when the switch is opened because its cam follower rides off the high dwell portion of cam 71. Cam 72 starts its rise in 42 seconds from zero position and completes it in 47 seconds, whereupon switch 10 will be opened. Once opened, switch 10 cannot be closed until it has been manually reset. This can be accomplished in various ways, as will be readily understood by those skilled in the art. As shown conventionally herein, the blade 77 of switch 10 is of resilient material and, when its free end is snapped past the pointed end of abutment 78, it is retained by the latter in open position, as indicated by dotted lines. The blade 77 may be moved back into its normal position by manual pressure on the reset button 79, provided that the cam 72 is then so positioned that some part of the low dwell portion of the cam lies opposite the cam follower, which occurs at both ends of the range of travel of shaft 61.

The operation will next be described. On a demand for heat from the burner, the thermostat switch 14 closes, thereby energizing the relay 15. The latter, when energized, closes the two sets of contacts 16 and 17. A circuit is established from transformer secondary 12 through the heater 40 of electronic tube 35. Another circuit is established through the timing motor 24, as follows: from terminal 1, wire 3, limit switch 9, wire 4, safety switch 10, wire 18, contacts 16, wires 19 and 20, capacitor 21, resistors 22 and 23, field 24, wires 25, 26 and 27 to terminal 2. The circuit to the timing motor and the circuit to the heater are simultaneously established. The heating of tube 35 requires approximately ten seconds and twelve seconds elapses before the shaft 61 has traveled far enough to close switch 28. The closing of the latter serves to connect the plate-cathode circuit of tube 35 directly across the motor field 24. After the shaft 61 has been turning for 17 seconds, the switch 29 closes and this starts the burner motor 30 and the ignition means 31, the circuit being traced as follows: from terminal 1, through wire 3, limit switch 9, wire 4, safety switch 10, wire 18, contacts 16, wires 19 and 32, switch 29, wire 33 to motor 30 and ignition means 31, and then by wires 34 and 27 to terminal 2. The timing motor continues to turn shaft 61 in a clockwise direction until combustion occurs, or until safety switch 10 opens, whichever event occurs first. In the particular example herein disclosed, an interval of 30 seconds after closing of the switch 29 is required for the shaft 61 to turn to the position wherein the safety switch 10 opens. Normally, combustion will occur within this interval. If combustion does occur within this interval, the phototube 47 starts the electronic tube 35 and the timing motor 24 is stopped and held magnetically in its stopped position. If combustion does not occur within said interval, the timing shaft 61 continues to be turned by the timing motor and will eventually cause safety switch 10 to open and be held open until manually reset. Opening of switch 10 will deenergize the primary 6 of transformer 7, thus deenergizing relay 15, causing the opening of contacts 16 and 17, whereupon the burner motor 30 and ignition means 31 are stopped and the timing motor and the heater of tube 35 are deenergized. On deenergization of the timing motor, shaft 61 will be turned backwards by spring 75 to the initial position illustrated in Fig. 5. Switches 28 and 29 will thus be opened and cam 71 will become so positioned that switch 10 can be manually closed by the reset button 79. On closure of switch 10, recycling will occur, the relay 15 closing contacts 16 and 17, starting the timing motor and the heater for tube 35, whereby the switches 28 and 29 will be successively closed as before. If combustion then occurs, the timing motor will be stopped as described. Assuming that combustion does occur and continues until the demand for heat is satisfied, the thermostat switch 14 will open, deenergizing coil 15, causing contacts 16 and 17 to open, whereby the heater 40, motor 30, ignition means 31 and the field 24 of the timing motor are deenergized. As the timing motor is deenergized, the clutch, comprising the gears 57 and 59, is opened, allowing shaft 61 to be turned back to zero position by spring 75. This movement of shaft 61 will open switches 28 and 29 in readiness for another cycle of operation when another demand for heat occurs. If during operation of the burner, the limit control switch 9 should open, the apparatus is stopped in the same manner as if the safety switch 10 opened, except that it will recycle without manual resetting when the limit is satisfied. If flame failure occurs during any run after combustion has been initiated, the timing motor will start up and cause the switch 10 to open unless combustion occurs during the 30 second interval described, in which case the timing motor will stop and normal burner operation will continue.

The sensitivity of the combustion control to response to flame is controlled by the size of the capacitor 51 and the amount of the grid bias obtained by the drop in voltage through the resistor 23. By these means, the intensity of flame necessary to secure actuation of the electronic tube and resultant stopping of the timing motor may be varied within limits as desired. If for example, the burner nozzle becomes partially plugged, resulting in a poor and stringy fire, the timing motor will be released and the cam shaft 61 will be driven on until the safety switch 10 opens.

The control is designed to fail safe in the event of failure of any of its component parts. In the event of a broken or defective phototube 47 or open wiring in the phototube circuit, the tube 35 will not operate. Accordingly, the timing motor will continue in operation until it opens switch 10 and causes a safety shut down of the burner. In the event of a short-circuited phototube, shorted or grounded phototube wiring, moisture or leakage across the phototube sufficient to cause trouble, stray light of sufficeint intensity to cause trouble, after-fire in the combustion chamber, or a defective electronic tube which operates in the absence of flame, the tube 35 is activated as soon as switch 28 is closed and the timing motor is locked before it has turned shaft 61 far enough to close the switch 29, whereby the burner cannot start.

In case there is a short circuit from the plate to the cathode in tube 35, the field 24 of the timing motor will be deenergized and the gear 57 will move out of mesh with gear 59, allowing spring 75 to reset shaft 61 to zero and open switch 28. The timing motor will again start and the described cycle of operation will be repeated indefinitely. However, no harm results because the current flow is limited by capacitor

21 and resistors 22 and 23 and because the burner cannot start.

In case the capacitor 21 becomes short circuited, the tube 35 will be unable to lock the timing motor and will be overloaded in attempting to do so. The timing motor will turn until the safety switch 10 opens and stops the burner. The resistor 22 may burn out as the result of heavy current through tube 35 and, if it does, the field of the timing motor is deenergized and the timing shaft automatically resets to zero position. If this same capacitor has an open circuit in the connection to its plates, the timing motor cannot start and the burner cannot be started. If the capacitor 51 becomes short circuited, the tube 35 is activated to lock the timing motor as soon as switch 28 closes and the burner cannot start. If the capacitor 51 is open circuited, either of two things may happen, viz., the tube 35 will be activated when switch 28 closes in which case the burner cannot start, or the tube 35 will not be activated at all and there will be a safety shut-down of the burner when switch 10 opens.

As to resistor failures, if resistor 23 is short circuited, the tube 35, as the result of loss of grid-bias, will lock the timing motor as soon as switch 28 closes and the burner cannot be started. If this resistor is open circuited, the timing motor cannot start. If resistor 22 is short circuited, the current in the timing motor and in the tube 35 will be slightly higher than normal but otherwise has no harmful effect.

In the event that the relay 15 is burned out, the timing motor cannot start and operation of the burner cannot occur. If the timing motor is burned out, or grounded or short circuited, the burner cannot start.

As to switch failures, if switch 28 fails to close, the tube 35 cannot lock the timing motor and the switch 10 is eventually opened to cause a safety shut-down of the burner. If switch 28 fails to open, because its contacts are welded together or for other reasons, all functions will nevertheless occur normally. This switch merely prevents the application of plate voltage to the tube 35 until the tube has heated up. If switch 29 fails to close, the burner cannot start and the timing motor continues to operate until switch 10 is opened to cause a safety shut-down of the control. In case switch 29 fails to open for any reason, the burner will start immediately on the closing of thermostat switch 14. If combustion occurs, the timing motor will be locked but if it does not occur, the timing motor will continue to operate until switch 10 opens and causes a safety shut-down of the burner. If switch 10 fails to close, the burner cannot be started and the entire control system is dead. If switch 10 fails to open for any reason, a safety shut-down will nevertheless occur because the shaft 61 will continue to turn until the stop 73 engages the right hand side of abutment 74, when switches 28 and 29 will open because their cam followers will ride off the steep drop, which interconnects the high and low dwell portions of the cams. The cam followers are locked in this position and manual attention is necessary before the burner can again be started. By manually opening the thermostat switch or by opening the circuit in which this switch is located, the electromagnetic pull on the clutch is broken and spring 75 can then turn the camshaft 61 back to its initial position, after the several cam followers have been pulled radially outward far enough to release the cams for movement. It is not necessarily essential in all cases to have the cam followers thus locked as described.

In case of failure of shaft 61 to reset because of a broken reset spring 75 or because the clutch gears do not disengage or because of excessive friction on the shaft 61, the timing motor will drive the shaft to running position, where switch 29 closes in the usual way. The same protection against combustion failure is present. The burner continues to operate until the thermostat is satisfied, when the relay contacts open and stop the burner and the timing motor. The shaft 61, however, does not reset. On the next call for heat, the burner starts immediately on closing of thermostat switch 14 and the timing motor starts. The tube 35 cannot lock the timing motor until its cathode is heated up and this takes from 7 to 10 seconds. Hence, camshaft 61 is driven along from its abnormal advanced starting position toward the safety shut-down position. About one third of the time interval between running and safety shut-down positions is used up. On the next succeeding call for heat, the burner will again operate as described, and shaft 61 will be moved close to safety shut-down position using up another third of said interval. On the next succeeding call for heat, the burner will again operate as described and this time, before the tube 35 can cause the timing motor to lock, the camshaft 61 will have moved far enough to cause switch 10 to open and cause a safety shut-down of the burner.

The invention has been described in its complete form. However, it is possible to dispense with some of the elements described and still obtain many of the advantages of the invention.

For example the switch 28 with its actuating cam 70 may be omitted if desired. Such an arrangement is shown in Fig. 2, wherein a single wire 43′ connects one terminal of the timing motor 24 to the cathode 38 and shielding grid 39 of tube 35, instead of the wires 42 and 43 shown in Fig. 1. All other connections are the same as in Fig. 1 and the operation is substantially the same, differing only in that plate voltage is immediately applied to the tube 35, when thermostat switch 14 closes, instead of waiting until the cathode 38 has become heated. The switch 29 is a refinement which, while often desirable, is nevertheless not essential for the reason that no harm is done to the tube 35 provided that sufficient grid bias is present to prevent flow of plate current until such time as the tube cathode has reached its normal operating temperature.

The operation of the control system of Fig. 2 is essentially the same as the system of Fig. 1. There is the same protection against failure of component parts of the system, as above described in connection with Fig. 1, except for that failure due to a short circuit between the plate and cathode of the electronic tube 35. With switch 28 omitted, such a failure results in a permanent short circuit of the timing motor 24, which therefore can never start, instead of continuous recycling of the timing motor as previously described. A further advantage is that a shorted circuited phototube, or similar failure, will cause a premature locking of the timing motor as soon as the tube heater reaches operating temperature (in 7 to 10 seconds), rather than at the time of closing of switch 28 (12 seconds) as described in connection with Fig. 1. While this may be an improper method of operation of certain electronic tubes, such as thyratrons, nevertheless this operation would be likely to occur only at rare intervals following the failure of some other part.

In Fig 3, another variation of the control system is shown. Here the switch 28 is dispensed with as in Fig. 2 and, in addition, the safety switch 10 is omitted. The wires 4 and 5 are directly interconnected instead of being connected through the switch 10 as heretofore. With switch 10 omitted, a safety shut-down is effected, as above described, when the shaft 61 travels to the end of its range of clockwise movement. The switch 29 will then open and stop the burner. Recycling will occur, when thermostat switch 14 is opened or its circuit otherwise opened, and the follower of switch 29 is drawn radially outward far enough to release the cam for return movement to zero position by spring 75.

In Fig. 6, there is shown an improved control system which provides protection in case the control shaft 61 fails to reset for any reason. In this system, the shaft 61 is driven in one direction (clockwise) by the rotor 54 of the timing motor from the initial position shown until the timing motor is stopped by the occurrence of combustion or, in case combustion does not occur, to the limit position, wherein the stop 73 abuts the opposite side of the fixed stop 74. The spring 75, as before, tends to reset shaft 61, whenever the field winding 24 of the timing motor is deenergized and the clutch opens. The shaft 61 in this case carries a single cam 80 having a rise of 45 degrees, an ensuing high dwell of 135 degrees and then a low dwell of 180 degrees. A spring switch blade 81 carries a roll 82 which is adapted to ride on cam 80 and which is pressed against the cam by the spring of the blade or in any other suitable way. The blade carries a contact 83 which is adapted to engage a contact 84, when roll 82 rides on the low dwell of the cam, and which is adapted to be disengaged from contact 84 and engaged with a second contact 85, when the roll 82 rides on the high dwell of the cam.

The contacts 83 and 84 are in series in the primary circuit of transformer 7. This circuit may be traced as follows, from terminal 1 by wire 86, limit switch 9, wires 87 and 88, contacts 84 and 83, blade 81, wire 89 to primary 6 and thence by wire 90 to terminal 2. The primary 6 is thus energized. The relay coil 15, as before, is controlled by a room thermostat switch 14 in a low tension circuit including the secondary 11, wires 91, 92, 93 and 94, and a pair of contacts 95 and 96, which are normally held in engagement by a spring 97. The relay coil 15, when energized by closing of thermostat switch 14 on a demand for heat, closes two pairs of contacts. The contacts 98 and 99 of one pair are connected by wires 100 and 101 to wires 89 and 88, respectively, and thus they are in parallel with the contacts 83 and 84. The contacts 102 and 103 of the other pair control the timing motor. Contact 103 is connected to wire 101. Contact 102 is connected by a wire 104 to a capacitor 105 and the latter is connected by a wire 106 to a resistor 107. The latter is connected by a wire 108 to one terminal of the main field winding 24 of the timing motor. The other terminal of winding 24 is connected by a wire 109, resistor 110, and wire 111 to wire 90 and thus to terminal 2.

When the relay pulls in, the field 24 of the timing motor is energized and shaft 61 is started on its clockwise travel. The first action is for cam 80 to cause contacts 83 and 84 to separate but the circuit to the primary 6 is maintained because the contacts 98 and 99 have previously been engaged. The next action is for the contacts 83 and 85 to engage and this starts the burner motor 30 and the electric or electrically-controlled ignition 31, the contact 85 being connected to both 30 and 31 by a wire 112 and both 30 and 31 being connected to wire 111. The shaft 61 is arranged to turn ¾ revolution per minute, for example. Thus, the burner motor 30 and ignition 31 are rendered active in 10 seconds, which gives sufficient time for the heater 40 to heat the electronic tube 35 in case such action is required. As shown, the heater 40 is permanently connected by wires 113 and 114 to the secondary 12 and is not cut out by a switch, as heretofore described. Thus, the electronic tube 35 will normally be heated. However, if the burner is stopped by the limit control 9, the circuit of primary 6 will be opened and the secondary 12 which supplies the heater 40, will not be energized and thus the tube 35 will be cool, when the burner is next started. But the burner cannot be started by the subsequent closing of the limit control because the relay will drop out when the transformer 7 is deenergized and thus separate the contacts 98 and 99, causing a break in the circuit to primary 6 which break cannot be closed except by the closure of contacts 83 and 84, which occurs only after shaft 61 has been reset by its spring, following deenergization of the motor field 24 by the opening of contacts 102 and 103, when the relay dropped out.

The electronic tube 35 functions as before to stop the timing motor in the event that combustion occurs. Its plate 36 is connected by a wire 115 to wire 108 and its cathode 38 is connected to wire 109. Thus, the plate-cathode circuit is connected in parallel with the winding 24 of the timing motor. One terminal of the phototube 47 is connected by a wire 116 to wire 115 and thus to the plate 36 while the other terminal is connected by wires 117 and 118, resistor 119 and wire 120 to the grid 37. Bias for the grid is provided by the voltage drop across the resistor 110. This bias is applied to the grid through a capacitor 51, the latter being connected by wires 121 and 122 to the wires 118 and 111, respectively. The resistor 119 is added to secure final or subsequent adjustment of control sensitivity. The shielding grid 39 is connected to wire 109. One wire 114 of the heater supply circuit is also connected to wire 109 by a wire 123. The circuits to the electronic tube differ slightly from those heretofore described. The phototube 47 is connected directly to the plate 36 instead of being grounded. The cathode 38 runs at practically ground level (except for the drop of a few volts in resistor 110) and more stable operation is secured in this way. Also, some metal tubes, which may be used, have their metal shell tied to the cathode and it would be objectionable to have this shell alive to the ground. A capacitor 124 of .1 microfarad capacity is respectively connected by wires 125 and 126 to the wires 106 and 111 for the purpose of eliminating radio interference. As one specific example, the capacitor 105 is of 1 microfarad capacity, resistors 107 and 110 are each of 150 ohms and one watt rating, resistor 119 is of ¼ megohm and one-half watt rating, and the timing motor is rated at 110 volts and normally draws 3.6 watts from the line.

While the arrangement of Fig. 6 differs in detail from that before described, it functions in the same general manner. That is, the phototube on receiving light from the burner flame activates the tube 35 and causes the flow of unidirectional current through the winding 24 of the timing motor to lock the rotor 54 of the same and thus timing shaft 61.

It will be clear that, if combustion occurs during the 30 second interval when roll 82 is riding on the 135 degree high dwell of cam 80, the shaft 61 will be stopped and held in stopped position by the locking of the timing motor. When the demand for heat is satisfied, thermostat switch 14 opens, deenergizing relay 15, which drops out, thereby opening the circuit to the winding 24 of the timing motor and the circuit of the primary winding 6. The clutch of the timing motor then opens and spring 75 moves the control shaft 61 back to its initial position. This results in stopping the burner by the separation of contacts 83 and 85 and in the reestablishment of the circuit to the primary 6 by the engagement of contacts 83 and 84.

Should combustion not occur, the phototube 47 will not activate the tube 35 and the timing motor will not be locked. Hence, shaft 61 will continue its clockwise travel until the pin 73 engages stop 74. A spring latch 127, which is moved out by pin 73 as it passes, moves back into position to prevent return movement of the pin and thus resetting of shaft 61. During the clockwise travel of shaft 61, the roll 82 ran off the end of the high dwell onto the low dwell of cam 80, and thus caused the contacts 83 and 85 to separate and stop the burner and also caused the engagement of contacts 83 and 84 to close the initial circuit to primary 6. The timing motor is still energized because the demand for heat is not satisfied, but it cannot turn shaft 61 clockwise because of stop 74. The spring 75 is prevented by the motor torque from turning the shaft counterclockwise. If the motor is deenergized by manually opening the thermostat switch, the spring 75 cannot completely reset shaft 61 because of the latch 127.

To recycle the control, the latch 127 is manually released by pushing button 128 which turns bellcrank 129 and by means of a link 130 pulls the latch out. This movement of the bellcrank also separates the above described contacts 95 and 96. Separation of these contacts opens the relay circuit, causing the contacts 98 and 99 and 102 and 103 to separate. The primary circuit of the transformer 7 is thus opened and the timing motor is stopped. The spring 75 can now move shaft 61 back to initial position. As shaft 61 moves back, the contacts 83 and 84 will again be separated and the contacts 83 and 85 will again be engaged but the burner will not start because contacts 98 and 99 are separated. As shaft 61 moves into its initial position, contacts 83 and 85 separate and contacts 83 and 84 engage. The circuit to the primary 6 is reestablished and the control is conditioned to respond to another call for heat.

It will be noted that the control shaft must be reset before it can again be moved in the direction necessary to start the burner. Hence, if the reset spring breaks, or the shaft 61 sticks in its bearings or the timing motor sticks in "on" position, the burner cannot be started. If such trouble occurs while the burner is operating, the burner will continue to operate until the demand for heat is satisfied, when the relay 15 will drop out and stop the burner and the timing motor. Subsequent closing of the thermostat switch will be ineffective because the primary circuit of the transformer 7 is held open by the then separated contacts 83 and 84.

The system of Fig. 7 is generally the same as that of Fig. 6 with the following exceptions. The cam 80' has a high dwell of 315 degrees which maintains contacts 83 and 84 separated and the contacts 83 and 85 engaged at all positions except the initial angular position of 45 degrees. The burner is stopped on safety by the momentary opening of the thermostat circuit by separation of the contacts 95 and 96. This occurs in 30 seconds after the burner switch is closed, if combustion does not occur. Separation of these contacts is effected by causing the pin 73 to engage the spring blade 131, on which contact 95 is mounted, and move it away from contact 96. This results in the dropping out of the relay and the stopping of the burner and the timing motor. Then, the shaft 61 starts to turn back by spring 75 and pin 73 moves back until it is stopped by latch 127. The contacts 95 and 96 thus reengage. The latch is released, as before, by pressing on the button 128 which draws out the latch in the same way as described in connection with Fig. 6. As in Fig. 6, resetting of the shaft 61 is necessary to a subsequent operation of the burner. The contacts 83 and 85 must separate and the contacts 83 and 84 must engage as a condition precedent to a subsequent operation of the burner. If the contacts 83 and 85 should weld together the burner could not be started because the contacts 83 and 84 must engage before the transformer can be energized. The system of Fig. 7 has the advantage over the system of Fig. 6 that the timing motor is deenergized whenever the burner is stopped by the safety means.

In the system of Fig. 6 and also that of Fig. 7, the circuit of the timing motor is in resonance before the tube 35 is activated. The circuit in each case is resonant and is so arranged by the use of the capacitor 105 and the resistors 107 and 110 that the voltage across the terminals of the main field winding of the timing motor is higher than the line voltage before the tube fires. For example, the voltage across the motor may be 125 with a line voltage of 115. With this arrangement, a large drop in line voltage can occur without reducing the voltage applied to the motor to such an extent that the motor cannot operate the timing shaft. For example, even if the line voltage drops to 85 volts, the voltage across the motor will still be about 93 volts which is sufficient for the purpose. When the tube 35 is activated, the resonance of the timing motor circuit is destroyed and the voltage across the terminals of said field winding drops below line voltage, say to 105 volts. Low voltage protection is secured by adjusting the relay 15 to pick up at about 95 volts and drop out when the voltage drops below 85. There will be no chattering of the relay, due to low voltage operation, because the instant the relay contacts open, the relay drops out and it can not pick up again until the voltage rises to 95 and at this voltage there will be no chatter.

The component parts of the system are for the most part standard articles which can be bought in quantities at low unit cost. Such are the electronic tube, phototube, resistors, capacitors, relay, switches, and transformer. The timing motor, including the timing shaft, gear train, with magnetic gear shift or clutch and reset spring, is also a standard article and one needs to add only the special cam or cams needed to actuate the switch or switches desired. There is nothing of a special or complicated nature to be manufactured and the various parts may be obtained and assembled into the system described at relatively low cost.

The various parts of the system may be assembled into a very compact unit occupying very little space. The complete timing motor unit occupies very little space and may be held in the palm of one hand. The switches may be the so-called "micro" switches, which are very small. The relay and transformer need be no larger than the timing motor unit. It is readily possible to mount all the parts in a space no larger than that occupied by the ordinary stack thermostat switch.

The invention thus provides an improved burner control which is simple, compact, relatively inexpensive to manufacture and one which is reliable in operation and unlikely to require much servicing. The control provides all the necessary safeguards against failures of the burner and against failure of the component parts of the system.

I claim:

1. In a burner control system, an alternating current timing motor, an electric circuit including said motor and an impedance, means to close said circuit on demand for heat from the burner and to open it when said demand is satisfied, an electronic tube having its plate-cathode circuit coupled to the terminals of said motor, a switch actuated by said motor a predetermined time after it is started to start the burner, a second switch actuated by said motor at another and later predetermined time after starting of the motor to stop the burner, means responsive to combustion at the burner to activate said tube and cause said motor to be stopped and magnetically held in its stopped position, whereby on failure of combustion at the burner the motor continues to turn and actuate said second switch to stop the burner.

2. In a burner control system, an alternating current timing motor, an electric circuit including said motor and an impedance, means to close said circuit on demand for heat from the burner and to open it when said demand is satisfied, an electronic tube having its plate-cathode circuit coupled to the terminals of said motor, a switch actuated by said motor a predetermined time after it is started to start the burner, a second switch actuated by said motor at another and later predetermined time after starting of the motor to stop the burner and the timing motor, means responsive to combustion at the burner to activate said tube and cause said motor to be stopped and magnetically held in its stopped position, whereby on failure of combustion at the burner the motor continues to turn and actuate said second switch to stop the burner and the timing motor.

3. In a burner control system, a single phase alternating current timing motor, an electric circuit including said motor and an impedance, means to close said circuit on demand for heat from the burner and to open it when said demand is satisfied, an electronic tube having its plate-cathode circuit coupled to the terminals of said motor, a switch actuated by said motor at a predetermined time after it is started to start the burner, means responsive to combustion at the burner to activate said tube and cause said motor to be stopped and magnetically held in its stopped position. and means to stop the burner

operable by continued movement of said motor after closing of said switch on failure of said tube to stop the motor.

4. In a burner control system, an alternating current timing motor, an electric circuit including said motor and an impedance, means to close said circuit on demand for heat from the burner and to open it when said demand is satisfied, an electronic tube having its plate-cathode circuit coupled to the terminals of said motor, a switch actuated by said motor a predetermined time after it is started to start the burner, a phototube responsive to combustion at the burner to activate said tube and cause said motor to be stopped and held in its stopped position, and means to stop the burner operable by continued movement of said motor after closing of said switch on failure of said tube to stop the motor.

5. In a burner control system, an alternating current timing motor, an electric circuit including said motor and an impedance, means to close said circuit on demand for heat from the burner and to open it when said demand is satisfied, an electronic tube having its plate-cathode circuit coupled to the terminals of said motor, a switch actuated by said motor a predetermined time after it is started to start the burner, a phototube responsive to combustion at the burner to activate said tube and cause said motor to be stopped and held in its stopped position, and means to stop the burner operable by continued movement of said motor after closing of said switch on failure of said phototube to cause said motor to stop.

6. In a burner control system, an alternating current timing motor, an electric circuit including said motor and an impedance, means to close said circuit on demand for heat from the burner and to open it when said demand is satisfied, an electronic tube having its plate-cathode circuit coupled to the terminals of said motor, a switch actuated by said motor a predetermined time after it is started to start the burner, a second switch actuated by said motor at another and later predetermined time after starting of the motor to stop the burner, a phototube responsive to combustion at the burner to activate said tube and cause said motor to be stopped and held in its stopped position, whereby on failure of combustion at the burner the motor continues to turn and actuate said second switch to stop the burner.

7. In a burner control system, an alternating current motor, a clutch, a member driven in one direction from initial position by the motor through said clutch at a predetermined time rate, means for moving said member to initial position when said clutch is released, an electric circuit including said motor and an impedance, means for closing said circuit on a demand for heat from the burner to start said motor and close said clutch and for opening such circuit when said demand is satisfied to stop the motor and open said clutch, an electronic tube, a circuit including the plate and cathode of said tube and coupled to said motor, means actuated by said member a predetermined time after it is started by said motor to start the burner, means responsive to combustion at the burner to activate said tube and stop the motor and thus said member, and means to stop said burner actuated by said member on continuance of its movement in the event of failure of the combustion responsive means to stop said motor.

8. In a burner control system, an alternating current motor, a circuit therefor including an impedance comprising in series a capacitor and a resistor, a first switch to respectively close and open said circuit when there is a demand for heat from the burner and when such demand is satisfied, a clutch, a member driven in one direction from an initial position by said motor through said clutch at a predetermined time rate, means for closing and opening the clutch respectively operable by the energization and deenergization of the timing motor, means for returning said member to initial position when said clutch is opened, an electronic tube having its plate-cathode circuit coupled to the terminals of said motor, heating means for said tube started and stopped coincidentally with the starting and stopping of the timing motor, a phototube responsive to combustion at the burner and connected to the grid of said tube and adapted to activate said tube and stop said motor, a bias for said tube, a second switch actuated by said member a predetermined time after said motor is started to start the burner, and a third switch actuated by said member to stop the burner on continued movement of said member after failure of said tube to stop the motor.

9. In a burner control system, an alternating current motor, a clutch, a member driven in one direction from initial position by the motor through said clutch at a predetermined time rate, means for moving said member to initial position when said clutch is released, an electric circuit including said motor and an impedance, means for closing said circuit on a demand for heat from the burner to start said motor and close said clutch and for opening such circuit when said demand is satisfied to stop the motor and open said clutch, an electronic tube, a circuit including the plate and cathode of said tube and coupled to said motor, means actuated by said member a predetermined time after it is started by said motor to close the last-named circuit, means actuated by said member a predetermined time after the closing of the last-named circuit to start the burner, means responsive to combustion at the burner to activate said tube and stop the motor and thus said member, and means to stop said burner actuated by said member on continuance of its movement in the event of failure of the combustion responsive means to stop said motor.

10. In a burner control system, an alternating current motor, a clutch, a member driven in one direction from an initial position by the motor through said clutch at a predetermined time rate, means for moving said member back to initial position when said clutch is released, an electric circuit including said motor and an impedance; means for closing said circuit on a demand for heat from the burner to energize said motor, close said clutch and drive said member and for opening such circuit when said demand is satisfied to deenergize the motor, open said clutch and allow said member to be moved back to its initial position by said first-named means, an electronic tube, a circuit including the plate and cathode of said tube and coupled in parallel with said motor, means actuated by said member shortly after it is moved from said initial position by said motor to start the burner, means responsive to combustion at the burner to activate said tube and stop the motor independently of the second-named means and thus stop said member, means operable by continued movement of said member in said direction to a second position to stop the burner, and means for preventing return of said

member to initial position when stopped in its second position, said preventing means being manually releasable to allow said member to be restored to initial position by the first-named means.

11. In a burner control system, an alternating current motor, a clutch, a member driven in one direction from an initial position by the motor through said clutch at a predetermined time rate, means for moving said member back to initial position when said clutch is released, an electric circuit including said motor and an impedance; means for closing said circuit on a demand for heat from the burner to energize said motor, close said clutch and drive said member and for opening such circuit when said demand is satisfied to deenergize the motor, open said clutch and allow said member to be moved back to its initial position by said first-named means, an electronic tube, a circuit including the plate and cathode of said tube and coupled in parallel with said motor, means actuated by said member shortly after it is moved from said initial position by said motor to start the burner, means responsive to combustion at the burner to activate said tube and stop the motor independently of the second-named means and thus stop said member, means to stop the burner and deenergize the motor operable by said member on continued movement in said direction to a second position in the event of failure of the combustion-responsive means to stop said motor, and means for preventing return of said member to initial position when stopped in said second position, said preventing means being manually releasable to restore said member to initial position.

12. In a burner control system, a timing member, an alternating current motor for moving said member in one direction and capable of moving it from an initial position to a second position, means tending to move said member back to initial position on deenergization of said motor, a circuit including said motor and an impedance, a control switch to close said circuit and start said motor and member on a demand for heat from the burner and to open the circuit when the demand for heat is satisfied and allow said member to be returned to its initial position by the first-named means, means actuated by said member after a predetermined movement in said direction from initial position to start the burner and for stopping the burner when the member moves to its second position; an electronic tube having its plate-cathode circuit coupled in parallel with the motor, means responsive to combustion at the burner to activate said tube and cause said motor to be stopped and magnetically held in its stopped position, and means compelling return of said member to initial position before said circuit can again be closed by said switch.

13. In a burner control system, a timing member, an alternating current motor for moving said member in one direction and capable of moving it from an initial position to a second position in a predetermined time, means tending to move said member back to initial position when the motor is deenergized, a circuit including said motor and an impedance, a relay operable when energized to close said circuit, a primary control switch operable on a demand for heat from the burner to cause energization of the relay and operable when the demand is satisfied to cause deenergization of the relay, means operable by movement of said member shortly after it is moved away from initial position to start the burner and operable when the member moves into the second position to stop the burner, an electronic tube having its plate-cathode circuit connected in parallel with said motor, means responsive to combustion at the burner to activate the tube and cause the motor to be stopped and magnetically held in its stopped position, a pair of contacts closed and opened when the relay is respectively energized and deenergized, a second pair of contacts connected in parallel with the first pair of contacts and closed and opened respectively when said member is in or out of initial position, the opening of both sets of contacts preventing energization of the relay, whereby when the relay is deenergized the first pair of contacts open and the second pair of contacts remain open until said member is reset to initial position.

14. In a burner control system, a single phase alternating current motor having a main field winding and a shaded pole winding for starting purposes, a circuit including said main field winding and adapted for connection to a supply of alternating current, an electronic tube having its plate-cathode circuit connected in parallel with said main field winding in the first-named circuit, a capacitor and a resistor in the first-named circuit in series with the plate-cathode circuit and with said winding and of such values as to produce resonance at the frequency of said supply and to cause the effective voltage across said terminals to be substantially greater than the effective voltage of said supply, a timing member driven away from an initial position by said motor, means for closing the first-named circuit on a demand for heat from the burner and starting said motor and for opening said circuit and deenergizing said motor when said demand is satisfied, means to start the burner operable after a predetermined movement of said member, means to stop the burner operable after a further predetermined movement of said member, means responsive to combustion at the burner to activate said tube and cause said motor to be stopped and magnetically held in stopped position, and means for resetting said member to its initial position when the motor is deenergized, said tube when activated destroying the resonance of the first-named circuit and causing the effective voltage across said terminals to drop to at least substantially that of said supply to reduce the current in the motor to a safe value during the period of operation of the burner.

15. In a burner control system, a timing member, a motor for moving said member in one direction from an initial position to a second position in a predetermined time, means tending to move said member back to initial position when the motor is deenergized, a circuit for said motor including a switch, an electromagnet for actuating said switch and operable when energized and deenergized to respectively close and open said switch to thereby open and close said circuit and energize and deenergize said motor, a primary control switch operable on a demand for heat from the burner to cause energization of said electromagnet and operable when the demand is satisfied to cause deenergization of the electromagnet, means operable by movement of said member shortly after it is moved away from initial position to start the burner, means operable when said member moves into its second position to stop the burner, means responsive to combustion at the burner to cause said motor to be stopped and held in its stopped position, a pair

of contacts closed and opened by said electromagnet when the latter is respectively energized and deenergized, and a second pair of contacts connected in parallel with the first pair of contacts and closed and opened by said member when the latter is respectively in or out of initial position, the opening of both pairs of contacts at the same time preventing energization of the electromagnet, whereby when the electromagnet is deenergized the first pair of contacts open and the second pair of contacts remain open until said member is moved back to initial position.

16. In a burner control system, a timing member, a motor for moving said member in one direction from an initial position to a second position in a predetermined time, means tending to move said member back to initial position when the motor is deenergized, a circuit for said motor including a switch, an electromagnet for actuating said switch and operable when energized and deenergized to respectively close and open said switch to thereby open and close said circuit and energize and deenergize said motor, a primary control switch operable on a demand for heat from the burner to cause energization of said electromagnet and operable when the demand is satisfied to cause deenergization of the electromagnet, means operable by movement of said member shortly after it is moved away from initial position to start the burner, means operable when said member moves into its second position to stop the burner, means responsive to combustion at the burner to cause said motor to be stopped and held in its stopped position, a pair of contacts closed and opened by said electromagnet when the latter is respectively energized and deenergized, a second pair of contacts connected in parallel with the first pair of contacts and closed and opened by said member when the latter is in or out of initial position, the opening of both pairs of contacts at the same time preventing energization of the electromagnet, whereby when the electromagnet is deenergized the first pair of contacts open and the second pair of contacts remain open until said member is moved back to initial position, and means operable when the burner is stopped by the third-named means to deenergize said electromagnet.

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