Jan. 6, 1953 E C. THOMSON ET AL 2,624,399

PROGRAM CIRCUIT FOR AUTOMATIC FURNACES

Filed Nov. 29, 1947 3 Sheets-Sheet 1

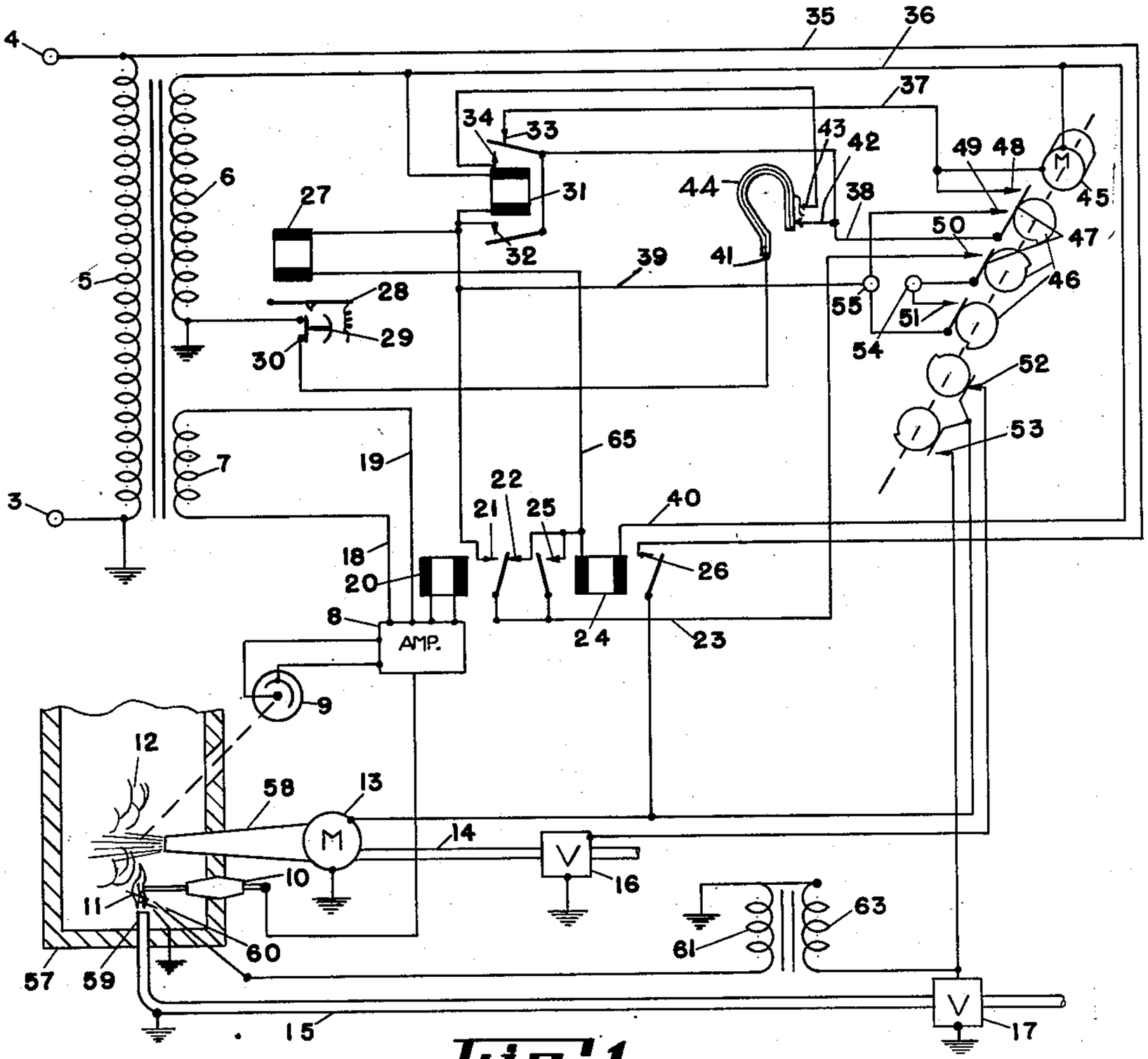

Fig. 1.

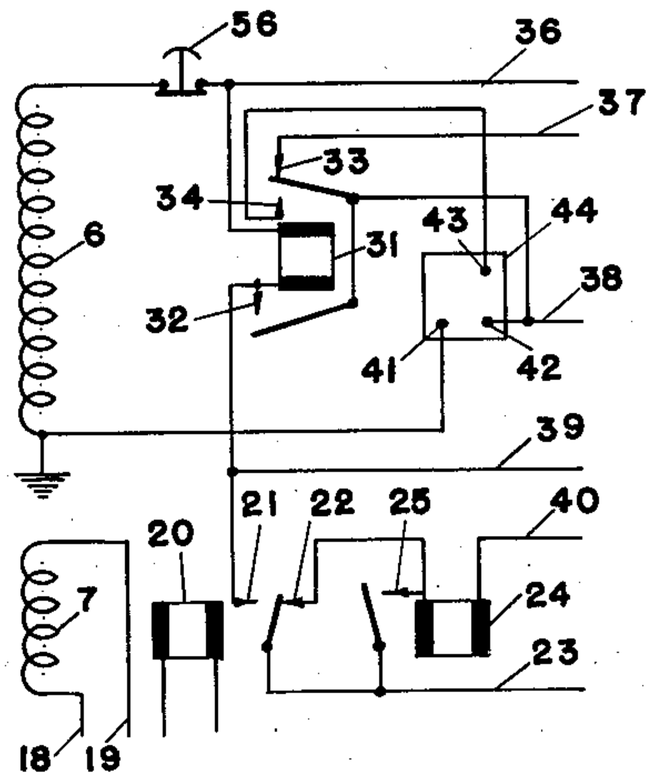

Fig. 2.

Inventors
E. CRAIG THOMSON
HERBERT J. WEBB

By MCMetcalf
Agent

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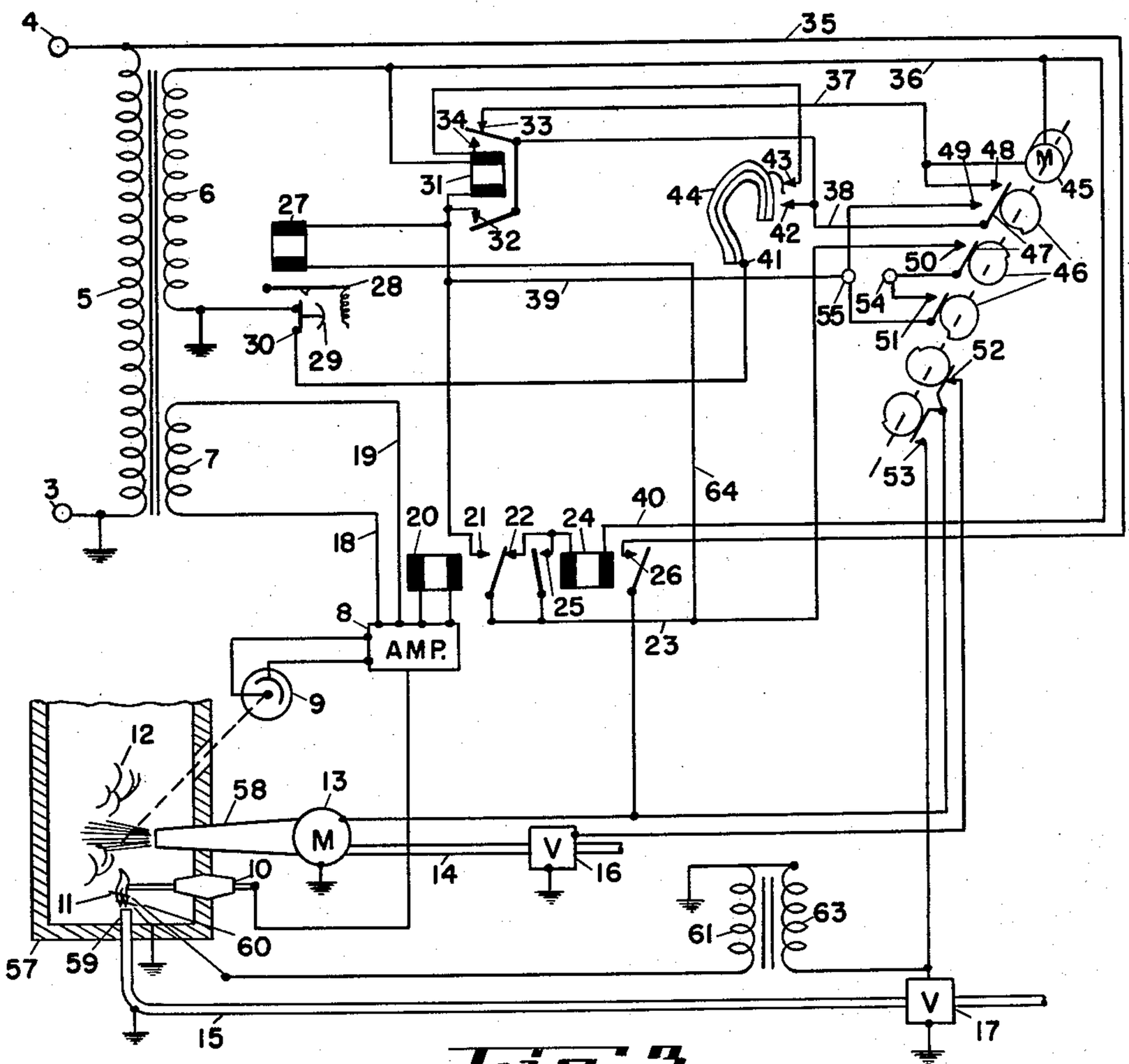

Fig. 3.

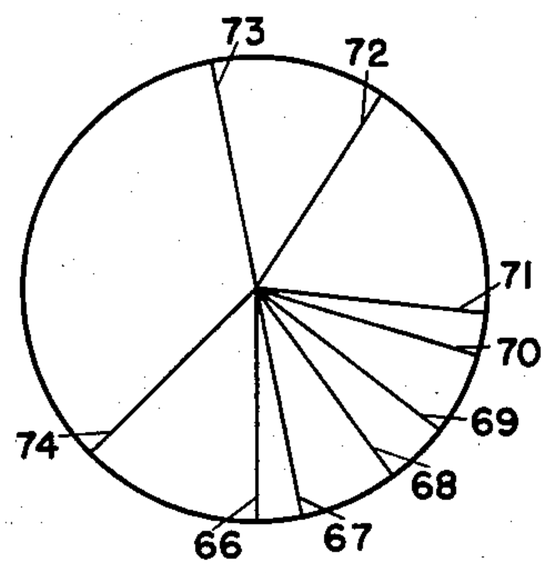

Fig. 4.

Inventors
E. CRAIG THOMSON
HERBERT J. WEBB

By McMetcalf
Agent

Jan. 6, 1953 E C. THOMSON ET AL 2,624,399

PROGRAM CIRCUIT FOR AUTOMATIC FURNACES

Filed Nov. 29, 1947 3 Sheets-Sheet 3

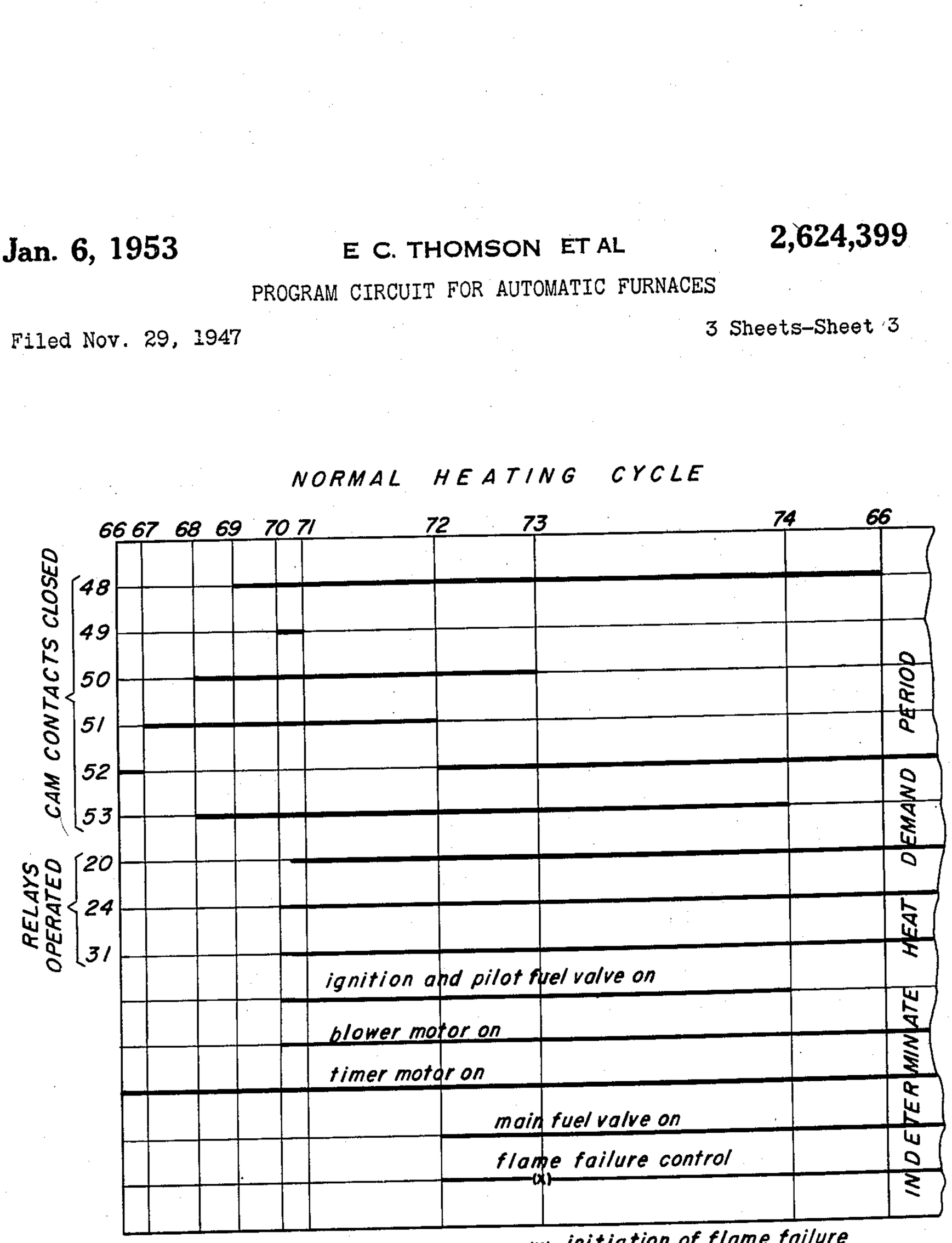

FIG. 5

INVENTORS
E. CRAIG THOMSON
HERBERT J. WEBB

BY Q. Y. Douras
ATTORNEY

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UNITED STATES PATENT OFFICE

2,624,399

PROGRAM CIRCUIT FOR AUTOMATIC FURNACES

E. Craig Thomson, Boston, and Herbert James Webb, Sharon, Mass., assignors to Combustion Control Corporation, Cambridge, Mass., a corporation of Massachusetts

Application November 29, 1947, Serial No. 788,836

2 Claims. (Cl. 158—28)

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This invention relates generally to electrically controlled fuel burners and particularly to controls suitable for industrial furnaces of the type known as "full automatic" in which the lighting of the burner at the beginning of each heating period is entirely controlled by an automatic timing device.

Industrial furnaces of the full automatic type, burning oil, pulverized fuel or gas, may employ either spark electrodes or a pilot burner to ignite the main burner. The pilot, if used, is ordinarily ignited by spark electrodes. The heating period is initiated by the closing of contacts in a thermostat, pressure switch or similar common type of control. In order to put the burner into operation at the beginning of each heating period, the ignition and fuel supply systems must be turned on in the proper sequence. This is frequently accomplished by a program relay, or automatic timer which closes and opens contacts in the various control circuits at predetermined intervals. The entire starting operation is known as the "starting cycle." On a typical burner, the burner motor and ignition are turned on together. If a pilot is used, the pilot valve is opened at the same time. After a certain interval during which the ignition or pilot flame becomes established, the main fuel valve is opened. After another interval, during which the main flame becomes established, the ignition is turned off leaving the burner in normal running condition. When the space or vessel to be heated reaches the desired temperature, the contacts of the thermostat open, shutting down the burner. When the thermostat contacts again close, the starting cycle is repeated. Because of the explosion hazard associated with large capacity industrial burners, a flame failure device is usually provided to shut down the burner in case of failure of the main flame or pilot or both, in order to prevent accumulation of unburned fuel in the combustion chamber. Since flame failure is usually an indication of faulty operation, it is essential that a burner shut-down from this cause, as distinguished from the normal shut-down at the end of heating period, result in some control or alarm action which requires attention of an operator before the burner can again be operated For this purpose a lockout device is ordinarily provided such as switch or push button in the vicinity of the burner which must be manually reset whenever it has opened.

The sequences and the delay periods between starting operations best suited for safe and efficient operation of different types of burners may

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vary widely; for example, on an oil fired furnace with a gas pilot, it is desirable that the flame failure device be put into control of the system immediately upon opening of the main fuel valve, whereas, on an oil furnace ignited by spark electrodes, it is necessary to maintain the flame failure device ineffective to shut down the burner for some period after opening of the fuel valve to allow sufficient time for the flame to ignite.

The general object of this inventoin is to proovide a control system of this type which is adaptable for use on a wide variety of automatic burners, which automatically performs the control functions necessary for starting the burner whenever the thermostat or other initiating control is closed, but which requires a manual reset for starting after a flame failure.

A further object is the provision of a number of inherent safety features in case of component failure in the control system without material increase in cost and complication.

These and other objects, advantages and novel features of the invention will be more fully apparent from the following description. The description refers to drawings in which:

Fig. 1 is a schematic illustration of the circuit in which the burner and timing switch are symbolically shown;

Fig. 2 is a simplified adaptation of Fig. 1, suitable in certain types of installation;

Fig. 3 is a second modification of the circuit shown in Fig. 1;

Fig. 4 is a circular time chart showing the sequence and relative duration of the various portions of the program operating cycle of this invention; and

Fig. 5 is a diagram of the programming of this invention during a proper burner operating cycle.

The control system comprises generally a timing switch in the form of a synchronous motor which drives a number of adjustable cams designed to open and close contacts in predetermined sequences, a flame failure detection device adapted to shut off the burner in case of flame failure during operation or failure to ignite during the starting cycle; a device such as a thermostat for initiating heating periods, and several magnetic relays for controlling the customary fuel valves and operating circuits of the burner. The timing switch used by way of illustration is more fully described in the co-pending application of Burton E. Shaw and Philip Giuffrida, Serial No. 262 filed January 2, 1948, and assigned to the assignee of this application.

Referring to Fig. 1, which illustrates a typical

full automatic control system employing the circuit of this invention, power for the entire electrical system is supplied from terminals 3 and 4. The current supply is ordinarily alternating, but the programming circuit here disclosed may be used with direct current. On furnace 57 is mounted main burner 58, which has an electrically driven motor 13 and is supplied with fuel through pipe 14 controlled by solenoid valve 16. A pilot burner 59, which is supplied with fuel through pipe 15 controlled by pilot 17, is also mounted in the furnace. The pilot is ignited in a well-kown manner by spark electrodes 60 excited by ignition transformer 61, the primary of which is connected in parallel with the pilot valve. The furnace is provided with a flame failure safeguard which is energized by secondary 7 and consists generally of a flame electrode 10 adapted to monitor the pilot flame, a photocell 9 which responds to light from the main flame, and an electronic amplifier 8, the output circuit of which maintains relay 20 energized as long as the presence of flame is detected by either the flame electrode or the photocell. The cam switch is here symbolically indicated as a plurality of cams 46 driven on a common shaft (not shown) by motor 45. Contact leaves 47 ride on the cams and engage contacts 48, 49, 50, 51, 52, and 53 in certain predetermined sequences as will be later described herein. A power relay 24 controls contact 26 which closes the circuit to burner motor 13 and, through contacts 52 and 53, to main valve 16 and pilot valve 17 respectively. A thermostat 44 is located in the room or building to be heated. Any other common type of control for initiating and terminating heating periods, for example, an aquastat, or pressure switch, may be used in place of, or in addition to, a thermostat. The thermostat shown here is of the three-wire type having contacts 41, 42 and 43. When the temperature of the room falls, contact 43 is connected to contact 41 first, and contact 42 to contact 41 a short time thereafter. When the temperature rises, contact 42 opens before 43. The burner system is further controlled by an auxiliary relay 31 which has a normally closed contact 33 and two normally open contacts 32 and 34. In this circuit a latching relay 27 is also provided. This relay operates latching arm 28. The reset button 29 is normally held by arm 28 against contacts 30 and is urged by a spring (not shown) away from the contacts so that when relay 27 becomes energized drawing back arm 28, the button opens and remains in the open position until manually reset.

The device of Fig. 1 operates as follows:

When the space where the thermostat is located cools to a certain temperature level, contact 43 of the thermostat engages contact 41. Since contact 43 leads only to normally open contact 34 of relay 31, no circuit is established. The room cools further and finally contact 42 also engages 41, completing the circuit from the ground side of secondary 6 through contacts 30, contacts 41 and 42, normally closed contact 33 to timer motor 45. The timer motor starts to rotate. At the beginning of the cycle, line 66 (Figs. 4 and 5), all the cam operated contacts are open, except contact 52. When the cams reach line 67 (Figs. 4 and 5), contact 52 opens and contact 51 closes. When the cams reach line 68 (Figs. 4 and 5), contacts 50 and 53 close. The closing of contact 53 establishes a circuit for the pilot valve 17 up to contact 26. As the timer motor continues to rotate contact 48 is closed at line 69 (Figs. 4 and 5), and then contact 49, at line 70 (Figs. 4 and 5). The closing of contact 49 establishes the energizing circuit for relay 31 from the ground side of secondary 6 through thermostat contacts 41 and 42, contact 49, terminal 55, relay 31 to wire 36. Relay 31 then closes contacts 32 and 34. The closing of contact 32 establishes a holding circuit for relay 31 by shunting the timer contact 49. The closing of contact 49 also energizes relay 24 by completing the circuit from the ground side of secondary 6 through contacts 41, 42, 49, 51, 50 and 22. Relay 24 closes contacts 25 and 26, establishing through 25 a holding circuit for the relay and through 26 a circuit to the burner motor 13, pilot valve 17, and ignition primary 63. Since contact 53 has been previously closed, the the pilot valve opens, the ignition electrodes are energized, and the burner motor starts to run. Shortly thereafter, at line 71 (Figs. 4 and 5), contact 49 opens, but this contact has been shunted by the closing of contact 32. Under normal conditions, the pilot ignites almost immediately, and, after a short interval, flame rod 10 operates through amplifier 8 to energize relay 20, opening contact 22 and closing contact 21. The circuit of relay 24 is held through contact 25. The closing of contact 21 establishes a shunt across timer contacts 50 and 51. When the cam reaches line 72 (Figs. 4 and 5), contact 51 opens and, at the same time, contact 52 closes. The terminals 54 and 55 may be disconnected as shown or may be bridged by a jumper. If they are not connected, the opening of contact 51 leaves the circuit of relay 24 held only through contact 21. At this time if the pilot is properly ignited, relay 20 is maintained energized by amplifier 8 in response to the detection of flame by the flame rod. The closing of contact 52 energizes the main fuel valve 16 and fuel is admitted to the main burner. After further rotation of the timer motor, to line 73 (Figs. 4 and 5), contact 50 opens. If terminals 54 and 55 are not connected, the opening of contact 51 has no effect, but if contact 51 is shunted by a jumper across the terminals, the circuit of relay 24 is held through 25, 50, 54 and 55 until 50 opens, providing a delay, which permits the main flame to become established before the flame failure control is put in control of the burner. At line 74 (Figs. 4 and 5), contact 53 opens, shutting off the ignition and pilot. Under normal conditions the main flame has become established and photocell 9 has begun to furnish the proper control signal to amplifier 8 to maintain relay 20 energized. The burner is then in normal operating condition with main relay 24 held through contact 21 of the flame failure relay 20. At the end of a full revolution of the timer motor, line 66 (Figs. 4 and 5), contact 48 opens, breaking the circuit to motor 45. The timer contacts are now in their original starting positions. When the room heats sufficiently, the thermostat contacts open de-energizing relays 31 and 24, and shutting down the burner. Upon cessation of the flame, relay 20 becomes de-energized and the entire system is in condition for recycling when the thermostat contacts close again.

In the starting cycle described above, the period between the starting of the timer motor and the energizing of the ignition and pilot, upon closing of contact 49, that is, the period during which the cams rotate from line 66 to line 70, is generally designated the "scavenging period." The interval between the start of ignition and the opening of the main valve, that is, the time for rotation from line 68 to line 72, is the "fuel valve

delay," between the opening of the main valve and the opening of contact **50**, that is, the time for rotation from line **72** to line **73**, the "priming" period, and between the opening of the main valve and the shutting off of the pilot, that is, the time for rotation from line **72** to line **74**, the "post-ignition" period.

During the entire programming cycle, the operating currents for the various circuit components are supplied through closed contact **30**. This requires that latching relay **27** remain deenergized throughout this cycle, otherwise relay **27** will open contact **30** causing all components to become deenergized. In the programming interval from **66** to **68**, no contact combination is created which can operate relay **27**. In the interval from **68** to the energization of relay **20**, usually between **70** and **71**, relay **27** is shunted by serially-connected contacts **50**, **51** and **22**. Thereafter, in response to the energization of relay **20**, serially-connected contacts **21** and **25** of relays **20** and **24**, respectively, shunt relay **27** so that as long as the furnace is ignited and operating normally the latching relay remains deenergized and contacts **30** are closed.

If the main flame becomes extinguished after it has once been ignited, relay **20** drops out, opening contact **21**. Relay **27** is no longer shunted and becomes energized, pulling in latching arm **28**. Switch **30** opens, breaking the circuit to contact **41** of the thermostat. The circuits to relays **24** and **31** and to the timer motor are broken and the burner cannot be started until button **29** is manually reset.

If the pilot fails to ignite, or is extinguished during the ignition period, relay **20** will remain de-energized and it is apparent that relay **27** will become energized upon the opening of the shunting contacts **50** and **51**.

If terminals **54** and **55** are not connected by a jumper the opening of contact **51**, which opens at the same time that contact **52** closes, will open the shunting circuit across relay **27** and the relay will operate to open push button **29** and produce the lockout condition described above with reference to flame failure during operation. If terminals **54** and **55** are bridged by a jumper, the shunt across relay **27** is not broken until contact **50** opens at the end of the priming period. The device is, therefore, adaptable to operate at zero priming period or with a certain delay. The priming period is that interval during which the main fuel valve is held open without requiring the presence of flame. It starts when the closure of contact **52** opens the main fuel valve. Contact **51** opens simultaneously with the closure of **52** (**72**, Figs. 4 and 5), so that if the pilot flame has not been previously detected and relay **20** operated, lock-out will occur immediately. With this contact operation, there is no time during which the main fuel valve can be opened without the prior presence of flame and the priming period is therefore zero. If there is a jumper between **54** and **55**, the opening of **51** has no effect, so that even if no flame is detected, lockout cannot occur until **50** opens, which occurrence is some time after the opening of the main fuel valve, and thus a finite priming period is provided.

Similarly, if the pilot is ignited but the main burner fails to ignite before the end of the post-ignition period relay **20** will be de-energized when the pilot is turned off and relay **27** will become energized producing a lockout through switch **30**. It is evident, therefore, that any type of flame failure or failure to ignite will result in the opening of push button **29** and operation of the burner will be prevented until the button is manually reset.

Provision is made in this circuit for preventing unsafe operation of the burner upon occurrence of most of the common type of component failures, in particular, electrical or mechanical failure of the relays. For example, a short or open circuit in the coil of relay **27** or a mechanical failure which prevents lockout does not impair the detecting function of the unit, but results in relay **31** remaining energized when relays **20** and **24** drop out upon flame failure. Contact **33** is then open, preventing the starting of timer motor **45**, so that the burner cannot be started. A similar failure in relay **31** leaves contact **32** open so that relay **24** drops out, shutting down the burner when contact **49** opens. A short circuit across the coil of relay **24**, while preventing operation of the burner, also results in a short circuit across secondary **6** when contact **49** closes. Since no power is then supplied to motor **45**, the motor stops.

If flame relay **20** fails to close because of electrical or mechanical failure, contact **21**, which normally shunts relay **27**, is open and lockout occurs when contact **50** opens, breaking the alternate shunt circuit provided by **50**, **51**, **22**, and **25**. If flame relay **20** is in the closed position at the beginning of a heating period, contact **22** is open, the energizing circuit to relay **24** is broken, and contact **25** remains open, breaking both shunt circuits across relay **27**.

Under the latter condition lockout occurs as soon as contact **49** closes. While contact **49** remains closed, it is apparent that resetting of button **29** will result in re-energizing relay **27**, so that the device repeatedly locks out, and timer motor **45** cannot be maintained energized except by holding in the button. This reaction is an aid to anyone servicing the equipment, as it indicates sticking of relay **20** rather than flame failure. In some installations, however, it may be preferable to permit motor **45** to run to the end of its cycle when relay **20** is stuck, even though the burner is not started because the energizing circuit to relay **24** is broken, as previously explained. For this type of operation, relay **27** may be connected to wire **23** and wire **65** omitted, as shown in Fig. 3, other connections remaining as Fig. 1. Relay **27** is then shunted by contact **21**, when relay **20** is stuck in the closed position, and a mechanical lockout will not occur. At the end of the cycle, however, relay **31** remains energized and the opening of contact **33** prevents recycling. Faulty operation of relay **20** may thus be distinguished from an ordinary flame failure, which would result in mechanical lockout and de-energizing of relay **31**. For observation during servicing, the timer motor may be recycled by manually releasing latch **28** to de-energize relay **31**, and then resetting. This checking operation may be safely performed when relay **20** is stuck, as relay **24** cannot become energized.

Figure 2 shows an adaptation of the circuit omitting latching relay **27**. A manually operated push button **56** is inserted between secondary **6** and wire **36**, and the push button **29** is omitted. Other connections not shown in this figure are the same as in Fig. 1, or Fig. 3. Such a circuit provides satisfactory lockout in certain installations where the thermostat is relatively in-

accessible or where some other type of initiating control is used, for example, a pressure switch.

In circuit of Fig. 2, a flame failure results in the opening of contact 21 by relay 20. Relay 24 becomes de-energized but relay 31 remains energized holding open contact 33. The burner, therefore, is shut down and starting of the timer motor is prevented by opening of contact 33. Push button 56 is provided to de-energize relay 31 and put the apparatus again into starting condition. It is evident that the apparatus of Fig. 2 could be put in starting condition by temporarily opening thermostat contacts 41 and 42, thereby de-energizing relay 31, and for this reason, the device of Fig. 1 is preferable if the thermostat is in a location where it might be subject to tampering. In pressure-switch controlled installations, the circuit of Fig. 2 is entirely satisfactory and has the advantage of omitting one relay with a resulting reduction in expense and complication of the circuit.

The circuit of Fig. 2 has a further advantage in that the reset button may be located at some distance from the remainder of the apparatus allowing for mounting in some position in the boiler room more convenient than that occupied by the control.

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

What is claimed is:

1. In programming apparatus for a furnace including main and pilot burners whose fuel flow is controlled by main and pilot fuel valves, means for igniting said pilot burner, a main burner blower motor, and a flame failure safeguard device; the improvement which comprises a cam assembly and at least six switches actuated thereby; a timer motor for rotating said cam assembly whereby said switches are sequentially closed; a thermostat switch; an auxiliary relay; a master power relay; a latching relay; an output relay actuated by said flame failure device in response to the detection of flame by said device; means including normally closed contacts of said latching relay, said thermostat switch, and normally closed contacts of said auxiliary relay for initially energizing said timer motor in response to a heat demand; means for initially preventing the operation of said latching relay after said timer motor has been energized; means including said normally closed contacts of said latching relay, said thermostat switch, and said first cam-actuated switch for subsequently energizing said timer motor; means including said normally closed contacts of said latching relay, said thermostat switch, and the second of said cam-actuated switches for subsequently energizing said auxiliary relay; means including normally open contacts of said auxiliary relay for shunting said second cam-actuated switch whereby said auxiliary relay is operated independently of said second cam-actuated switch; means including said normally closed contacts of said latching relay, said thermostat switch, said second, third and fourth cam-actuated switches, and normally closed contacts of said output relay for operating said power relay at the same time said auxiliary relay is operated; means including normally open contacts of said power relay for shunting said normally closed contacts of said output relay whereby said power relay is operated independently of said output relay; means including second normally open contacts of said master power relay and said sixth cam-actuated switch for operating said means for igniting said pilot burner and for opening said pilot fuel valve at the same time said master power relay is energized; means including said second normally open contacts of said master power relay for operating said main burner blower motor at the same time said pilot burner fuel valve is opened; means including normally open contacts of said output relay for shunting said third and fourth cam-actuated switches in response to the detection of said pilot flame by said flame failure safeguard device whereby an alternate energizing path for said master power relay is created dependent upon the operation of said output relay; said cam assembly including means for opening said fourth cam-actuated switch whereby continued energization of said power relay is dependent upon the continued operation of said output relay; means including said fifth cam-actuated switch and said second normally open contacts of said power relay for opening said main burner fuel valve simultaneously with the opening of said fourth cam-actuated switch; and means including the normally open contacts of said output relay for removing a shunt across said latching relay in response to a flame failure whereby the normally closed contacts of said latching relay open the energizing circuits for the programming components in response to a flame failure.

2. In programming apparatus for a furnace including main and pilot burners whose fuel flow is controlled by main and pilot fuel valves, means for igniting said pilot burner, a main burner blower motor, and flame failure safeguard device, the improvement which comprises a cam assembly and at least six switches actuated thereby; a timer motor for rotating said cam assembly whereby said switches are sequentially closed; a thermostat switch; an auxiliary relay; a master power relay; a latching relay; an output relay actuated by said flame failure device in response to the detection of flame by said device; means including normally closed contacts of said latching relay, said thermostat switch, and normally closed contacts of said auxiliary relay for initially energizing said timer motor in response to a heat demand; means for initially preventing the operation of said latching relay after said timer motor has been energized; means including said normally closed contacts of said latching relay, said thermostat switch, and said first cam-actuated switch for subsequently energizing said timer motor; means including said normally closed contacts of said latching relay, said thermostat switch, and the second of said cam-actuated switches for subsequently energizing said auxiliary relay; means including normally open contacts of said auxiliary relay for shunting said second cam-actuated switch whereby said auxiliary relay is operated independently of said second cam-actuated switch; means including said normally closed contacts of said latching relay, said thermostat switch, said second, third and fourth cam-actuated switches, and normally closed contacts of said output relay for operating said power relay at the same time said auxiliary relay is operated; means including normally open contacts of said power relay for shunt-

ing said normally closed contacts of said output relay whereby said power relay is operated independently of said output relay; means including second normally open contacts of said master power relay and said sixth cam-actuated switch for operating said means for igniting said pilot burner and for opening said pilot fuel valve at the same time said master power relay is energized; means including said second normally open contacts of said master power relay for operating said main burner blower motor at the same time said pilot burner fuel valve is opened; means including normally open contacts of said output relay for shunting said third and fourth cam-actuated switches in response to the detection of said pilot flame by said flame failure safeguard device whereby an alternate energizing path for said master power relay is created dependent upon the operation of said output relay; said cam assembly including means for opening said fourth cam-actuated switch whereby continued energization of said power relay is dependent upon the continued operation of said output relay; a plurality of terminals which when interconnected shunt said fourth cam-actuated switch whereby the opening of the third cam-actuated switch at a time subsequent to the opening of said fourth cam-actuated switch determines the point of time when the continued energization of said power relay is dependent upon the operation of said output relay; means including said fifth cam-actuated switch and said second normally open contacts of said power relay for opening said main burner fuel valve simultaneously with the opening of said fourth cam-actuated switch; and means including the normally open contacts of said output relay for removing a shunt across said latching relay in response to a flame failure whereby the normally closed contacts of said latching relay open the energizing circuits for the programming components in response to a flame failure.

E. CRAIG THOMSON.
HERBERT JAMES WEBB.

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