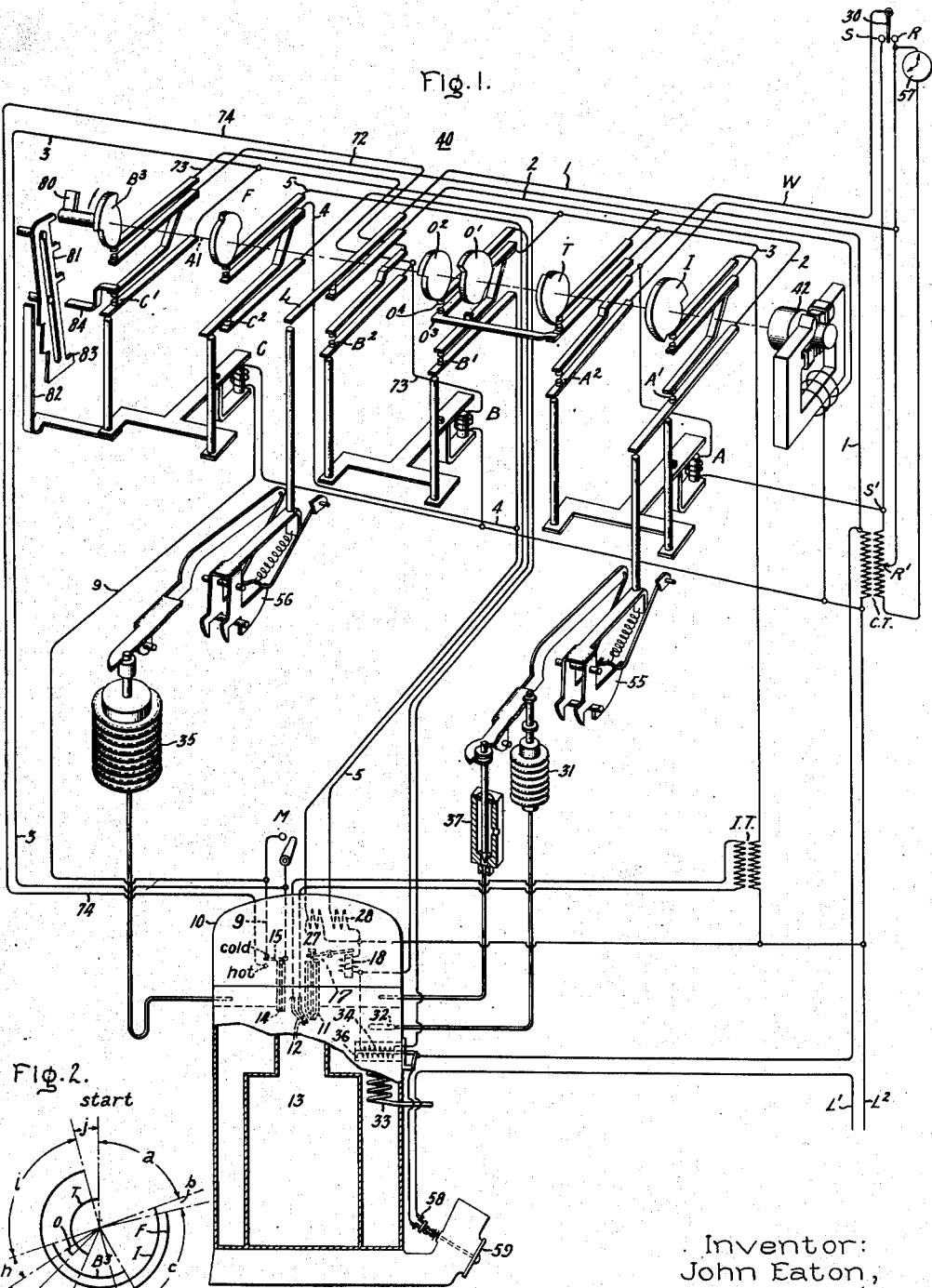


June 29, 1937.

J. EATON  
BURNER CONTROL

2,085,577

Original Filed July 14, 1934 2 Sheets-Sheet 1



Inventor:  
John Eaton,  
by *Harry E. Dunham*  
His Attorney.

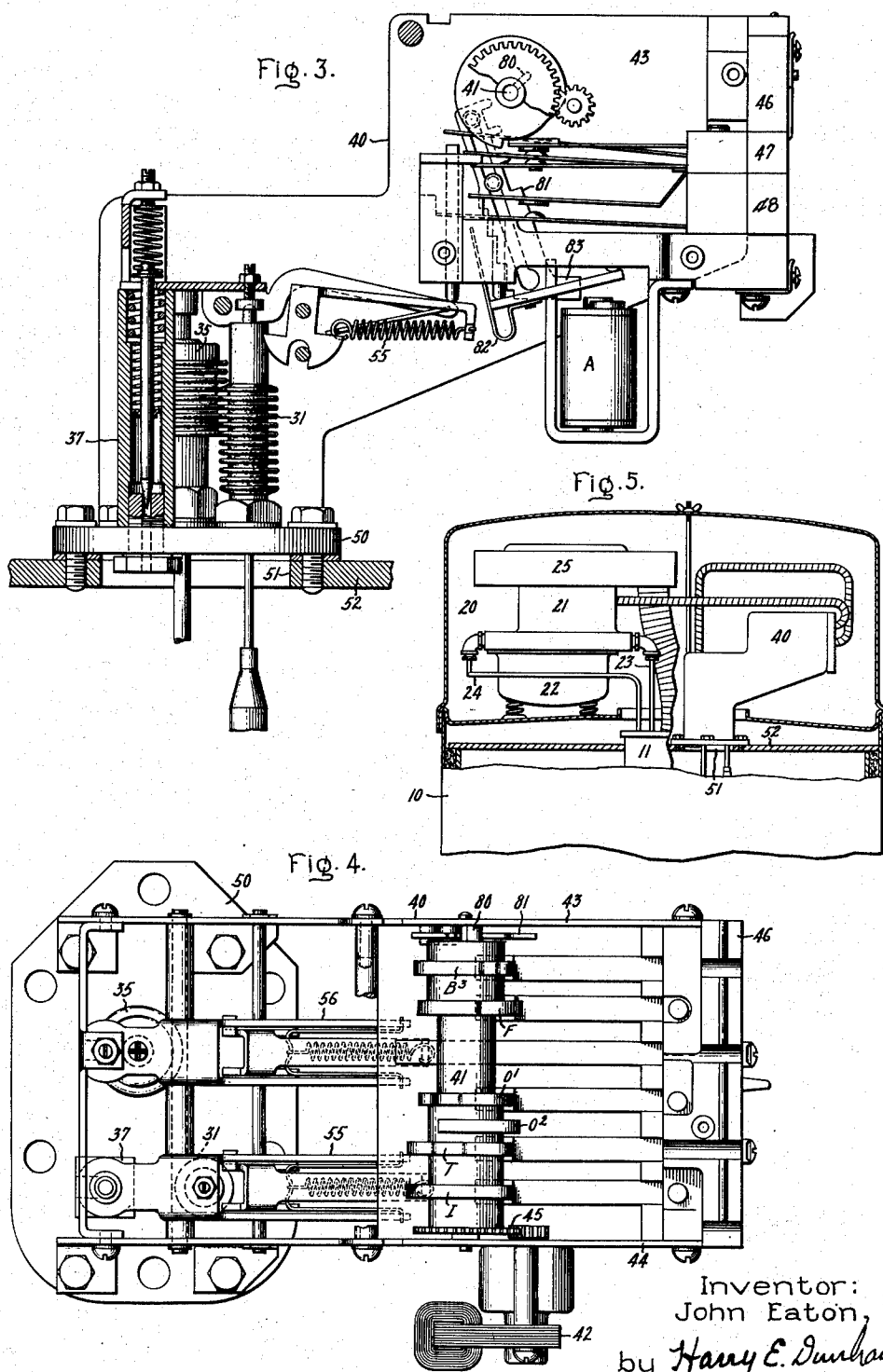
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## UNITED STATES PATENT OFFICE

2,085,577

## BURNER CONTROL

John Eaton, Schenectady, N. Y., assignor to  
General Electric Company, a corporation of  
New York

Original application July 14, 1934, Serial No.  
735,103. Divided and this application March  
14, 1935, Serial No. 11,100

29 Claims. (Cl. 158—28)

This application is a division of my application,  
Serial No. 735,103, filed July 14, 1934.

The invention relates to automatic fuel burner  
control systems and apparatus such as used with  
oil fired boiler furnaces for heating homes or in  
other similar service.

The principal object is to provide improve-  
ments which insure the maximum safety in the  
automatic control and operation of the fuel  
burner as well as safe operation of the boiler  
furnace.

A specific object is to provide an improved  
control system and apparatus for obtaining a  
predetermined timed sequence of the operations  
involved in introducing and igniting oil in the  
furnace in which the introduction of unburned oil  
into the furnace is automatically limited to a  
predetermined safe value upon failure to estab-  
lish combustion or upon failure of the oil burner  
mechanism and control apparatus to function  
properly.

Another specific object is to provide an auto-  
matic fuel burner control system and apparatus  
which insures detection of both the presence and  
absence of combustion with a minimum delay.

A still further object is to provide an improved  
form of combined room thermostat and limit con-  
trol for effecting operation of the fuel burner in  
accordance with both room temperature and cer-  
tain other conditions such as boiler temperature,  
domestic hot water temperature, steam pressure  
or the like.

Another important object is to provide a fully  
automatic fuel burner control system and appa-  
ratus which effectively ensures against continued  
operation of the burner in case of accidental fail-  
ure or faulty operation of the important safety  
control elements, such as the flame detector, the  
low water cutoff, the fuel supply control and the  
like.

It is also a special object to provide an improved  
unitary structural arrangement for the automatic  
fuel burner and boiler control mechanism whereby  
reliability, ease of installation, inspection and ad-  
justment of the various automatic operating ele-  
ments are obtained.

A preferred form of automatic oil burner con-  
trol system and apparatus embodying the im-  
provements of the present invention is illustrated  
in the accompanying drawings. Fig. 1 is a sche-  
matic diagram showing the improved form of oil  
burner safety control system and apparatus ap-  
plied to an electric motor driven oil burner me-  
chanism adapted for use in combination with a  
vacuum vapor house heating boiler; Fig. 2 is a

sequence diagram indicating the predetermined  
timed relations in which the various operations  
involved in starting the oil burner and establish-  
ing combustion are accomplished under the control  
of a room thermostat, a boiler thermostat or  
similar master control element, by the improved  
safety control system and apparatus shown in  
Fig. 1; Fig. 3 shows more fully the cooperating ar-  
rangement and detailed structure of the various  
elements of the oil burner timing control mecha-  
nism and certain of the safety control elements  
shown diagrammatically in Fig. 1; Fig. 4 is a top  
view of the timing and safety control mechanism  
shown in Fig. 3, and Fig. 5 is a view of the top  
part of the oil burner boiler showing more clearly  
the manner in which the oil burner mechanism  
and timing and safety control mechanism therefor  
is mounted on the boiler.

As diagrammatically shown in Fig. 1 the boiler  
furnace 10 is of the improved type described and  
claimed in the copending application of Henry  
S. Woodruff, Serial No. 676,651, filed June 20,  
1933, and assigned to the assignee of my present  
invention. It will be understood, however, that  
the improvements of my present invention are ap-  
plicable to control any ordinary type of automati-  
cally fired boiler or furnace.

The oil burner nozzle 11 supplies atomized oil  
which is ignited during the starting operation of  
the oil burner mechanism by an electric spark be-  
tween electrodes 12 to establish combustion in the  
boiler combustion chamber 13, in the manner de-  
scribed in detail hereinafter. A quick acting  
flame detector 14 having a control switch 15  
movable between the "cold" and "hot" positions  
is provided for detecting the presence or absence  
of combustion. As indicated the flame detector 14  
is of the expansible heat responsive type although  
any quick acting type of flame detector may be  
employed.

An oil control valve 17 is shown incorporated  
in the oil burner nozzle 11 for starting and stop-  
ping the supply of oil into the combustion cham-  
ber 13. Oil valve 17 is normally closed and is  
opened only when the oil valve operating electro-  
magnet 18 is energized. As pointed out hereafter  
electromagnet 18 is provided with a holding cir-  
cuit for maintaining valve 17 open after it is  
once opened independently of the initial ener-  
gizing circuit. As shown in Fig. 5 oil and air are  
supplied under pressure to the burner nozzle 11  
from the electric motor operated oil burner  
blower compressor mechanism 20.

The oil atomizing nozzle 11 and oil valve 17  
preferably are of the type described and claimed

in my copending joint application, Serial No. 391,320, filed September 28, 1933, although the present invention is not limited thereto.

The oil burner motor compressor mechanism 20 preferably is of the type described and claimed in the copending application of Walter O. Lum, Serial No. 737,063, filed July 26, 1934, and assigned to the assignee of my present invention. The oil burner mechanism 20 has an electric driving motor 21 which drives a suitable oil and air pumping means located inside of the tank 22 for pumping oil and air under pressure into the tank. The air under pressure is supplied from tank 22 directly to the burner nozzle through the pipe 23 and the oil under pressure is supplied to the nozzle upon opening of oil control valve 17 through the pipe 24. Low pressure combustion air is supplied from the blower 25. As indicated diagrammatically in Fig. 1 the oil burner motor 21 is provided with a running winding 27 and a starting winding 28.

The oil burner mechanism is operated under the control of the room thermostat 30 to heat the water in the boiler 10 to supply steam or vapor to a room heating radiator system (not shown). In addition the oil burner mechanism is also operated under the control of the water thermostat 31. As shown the water thermostat 31 is of the expansible bellows type having the bulb 32 responsive to the temperature of the water in the boiler 10. The thermostat 31 serves to operate the oil burner mechanism to maintain the boiler water temperature above a predetermined value sufficient to heat an adequate supply of domestic hot water by means of the water heating coil 33 which is shown immersed in the boiler water.

A bellows 35 is responsive to the pressure in boiler 10 and serves to shut down the oil burner mechanism whenever an excessive pressure occurs. An improved form of electrically heated low water cutoff switch mechanism 36 having a heater 34 is provided for preventing operation of the oil burner mechanism whenever the boiler water level falls to an unsafe value as described and claimed in the parent application.

A vacuum relief valve 37 is provided for venting the boiler in accordance with the invention described and claimed in the copending application of Walter O. Lum, Serial No. 735,128, filed July 13, 1934, and assigned to the assignee of my present invention. The improved arrangement whereby the vacuum relief valve 37 is operated directly by the domestic water temperature control thermostat 31 is an improvement of my present invention.

In order to obtain a predetermined timed sequence of operation of the various elements comprising the oil burner mechanism, a timing control device indicated generally by the reference numeral 40 is provided. In the preferred form indicated diagrammatically in Fig. 1 and shown more in structural detail in Figs. 3 and 4, a cam shaft 41 is driven by the electric timing motor 42 which preferably is of the alternating current constant speed type such as commonly used in electric clocks. The cam shaft 41 carries a series of timing cams indicated respectively as B<sup>1</sup>, F, O<sup>1</sup>, O<sup>2</sup>, T and I, all of which are rotated in unison in a clockwise direction as indicated by the arrow in Fig. 1 upon operation of the timing motor 42. Each of these cams has a corresponding cam operated switch contact mechanism arranged so that a definite series of switching operation is performed in timed sequence in

the manner described more fully hereinafter in connection with the operation.

Cooperating with the timing cam operated switch mechanism are a series of electromagnetically operated switches indicated as A, B and C, each having a pair of circuit controlling switch contacts indicated respectively at A<sup>1</sup>, A<sup>2</sup>, B<sup>1</sup>, B<sup>2</sup> and C<sup>1</sup>, C<sup>2</sup> in Fig. 1.

As shown more in detail in Figs. 3 and 4, the cam shaft 41 is rotatably supported between the side plates 43 and 44 with the motor 42 driving the cam shaft through the speed reducing gearing 45. The series of spring contacts operated by the cams B<sup>1</sup>, F, O<sup>1</sup>, O<sup>2</sup>, T and I are mounted between suitable blocks of insulating material 46 and 47. Likewise the spring switch contact mechanism of the electromagnetic switches A, B and C are mounted between blocks 47 and blocks 48, the operating electromagnets therefor being mounted below the contact mechanism as indicated in Fig. 3. The side plates 43 and 44 are secured to a cover plate 50. As indicated in Fig. 3 plate 50 is arranged to cover an opening 51 provided in the top wall 52 of boiler 10, being removably bolted in place with suitable gasket to seal the boiler wall.

The cover plate 50 carries the boiler water thermostat 31, the boiler pressure responsive bellows 35 and the vacuum relief valve 37, all as a unitary structure with the oil burner timing control mechanism 40. With this improved unitary arrangement, the expansible bellows thermostat 31 is connected through the over-center snap action spring operating mechanism 55 to mechanically operate the contact switch mechanism A<sup>1</sup> of the electromagnetic switch A. At the same time the thermostat 31 operates the vacuum relief valve 37. Similarly the expansible bellows of the boiler pressure responsive device 35 operates the spring contact switch L through the agency of the overcenter spring snap action mechanism 56.

The operation of the improved burner control system and apparatus illustrated is as follows: When the room thermostatic switch 30 calls for heat, the running contact R is closed. When the room thermostat exceeds the temperature which it is adjusted to maintain, the contact S is closed to stop the oil burner. While not shown in detail it will be understood that the electrically driven clock 57 serves to vary the setting of the room thermostat 30 to provide different day and night temperature in home heating service in the customary manner. When the room thermostat 30 closes the running contact R, the A electromagnetic switch or relay is energized. As shown in Fig. 1 the A relay is energized from the low voltage secondary winding of the control transformer CT having the primary winding thereof energized from a suitable alternating current power source L<sup>1</sup>, L<sup>2</sup> with the contacts of the low water cutoff switch 36 and also the safety plug switch 58 connected in the primary circuit. The safety switch 58 is arranged to be opened by the pressure relief door 59 in case an excessive pressure should develop within the combustion chamber 13 of the oil burner 10. Likewise the low water cutoff switch 36 opens in case the water in boiler 10 reaches a dangerously low level. However, upon the occurrence of either of these abnormal and unsafe conditions, the primary of the control transformer CT is deenergized thus effectively preventing further operation of the oil burner.

Under normal conditions the secondary wind-

ing of the control transformer CT is continuously energized and the relay A is energized therefrom through a circuit which may be traced from the intermediate point R<sup>1</sup> through contact R of thermostat 30 and thence through conductor W and the energizing winding of the electromagnetic relay A to the terminal S<sup>1</sup> of the transformer secondary winding. This results in operation of relay A to close both contacts A<sup>1</sup> and contacts A<sup>2</sup>. Contacts A<sup>2</sup> shunt the room thermostat contact R and connect the energizing winding of relay A directly to the terminals R<sup>1</sup> and S<sup>1</sup> of the transformer, thus maintaining relay A continuously energized independently of the room thermostat 30.

Upon closure of contacts A<sup>1</sup> an energizing circuit for the operating winding of relay C is closed provided the movable contact 15 of the flame detector 14 is in the cold position as indicated in Fig. 1.

Normally the flame detector 14 operates its movable control contact 15 to the cold position quickly in response to the absence of combustion in the combustion chamber 13 of the boiler 10. Relay C is energized from the supply line L<sup>1</sup>, through conductor 1, the normally closed contacts of the pressure limit switch L, conductor 2, contacts A<sup>1</sup>, conductor 3, the cold contacts of the flame detector 14, conductor 9, the winding of relay C and thence to the supply line L<sup>2</sup>.

Upon the resulting operation of relay C, the normally open contacts C<sup>1</sup> are closed and the normally closed contacts C<sup>2</sup> are opened. Contact C<sup>1</sup> establishes an energizing circuit for the timing motor 42. This circuit is traced from conductor 3 which remains energized from the supply line L<sup>1</sup> as long as the contacts A<sup>1</sup> and the limit contacts L remain closed, through contacts C<sup>1</sup> and conductor 72, the energizing winding of timing motor 42 to the supply line L<sup>2</sup>. Thereupon the timing motor 42 begins to rotate the series of timing cams carried by the shaft 41.

At the same time the opening of the normally closed contact C<sup>2</sup> prevents energization of the holding circuit of the oil valve operating electromagnet 18, this circuit being traced from the supply line L<sup>1</sup> through the safety door switch contact 58, the low water cutoff switch 36, the conductor 1, the limit switch L, the conductor 2, the contact A<sup>1</sup>, conductor 3, the contact B<sup>1</sup>, conductor 4, the normally closed contact C<sup>2</sup>, the electric heater 34 of the low water cutoff switch and thence through the energizing winding of the valve operating electromagnet 18 to the supply line L<sup>2</sup>. As will be pointed out hereinafter, this opening of the oil valve holding circuit is an important factor in insuring safe operation of the oil burner control.

As indicated in the sequence chart of Fig. 2, there is a considerable interval *a* of time after the starting of the timing motor 42 before the sequential operation of the timing cam switches begins. At the end of this interval *a* the cam I closes its contacts to energize the primary winding of the ignition transformer IT, the circuit extending from the conductor 3 which remains energized as previously pointed out through the contacts of the cam switch I, the primary of the ignition transformer to the supply line L<sup>2</sup>. The cam contact I remains closed to maintain the spark ignition electrode 12 energized from the high voltage secondary winding of the ignition transformer during almost the entire starting cycle of the oil burner. This insures that any oil supplied from the nozzle 11 at any time during

this cycle is ignited. This insures that ignition is always present to ignite any oil delivered from the oil burner nozzle 11 at any time during the starting cycle.

After a relatively short time interval *b*, the cam F operates to close its contact and establish a circuit preparatory to energizing the start winding of the oil burner motor. After a longer time interval *c*, cam B<sup>3</sup> operates to close its contact. Thereupon an energizing circuit for the relay B is established. This circuit is traced from conductor 3 which remains energized from the supply line L<sup>1</sup>, as previously pointed out, through contact C<sup>1</sup>, conductor 72, cam contact B<sup>3</sup> and thence through conductor 73 and the energizing winding of the operating electromagnet of relay B. Relay B responds to close both of its contacts B<sup>1</sup>, B<sup>2</sup>. Upon closure of contact B<sup>1</sup> both the start and the run windings of the oil burner motor are energized. The circuit for the running winding is traced from the conductor 3 which remains energized from supply line L<sup>1</sup> under normal conditions through the relay contact B<sup>1</sup>, conductor 4 and thence through the run winding to supply line L<sup>2</sup>. The energizing circuit of the start winding extends from conductor 4 through the previously closed cam contact F, conductor 5, and thence through the start winding to supply line L<sup>2</sup>. The oil burner driving motor immediately starts operation of the oil and air pumping means to pump oil and air under pressure into the tank 22 and to supply air from the blower 25 to the combustion chamber 13 of the boiler. However, under normal conditions there is no oil supplied into the combustion chamber due to the fact that the oil supply control valve 17 remains closed.

During the interval *d* the oil burner motor comes up to speed and operates with both the running and the starting winding energized. At the end of interval *d* cam F opens its contact to deenergize the starting winding and the oil burner motor continues at full speed operation with the run winding energized alone.

During the intervals *d* and *e*, the operation of the oil burner motor serves to build up full pressure of the oil and air in the tank 22, at the same time the ignition electrodes are in operation to provide a spark for igniting the oil. At the end of interval *e*, the cam T closes its contact to maintain the timing motor 42 energized through a circuit which is independent of the initial energizing circuit established by closure of contact C<sup>1</sup> as previously described. Upon closure of the cam contact T, the conductor 3 is connected directly through the T contact to conductor 72, thus maintaining the energizing winding of the timing motor 42 energized. The closure of cam contact T also maintains the operating winding of B relay energized independently of contact C<sup>1</sup> as long as the cam contact B<sup>3</sup> remains closed since the conductor 72 is connected to conductor 3 through the cam contact T.

All that remains to be done to establish combustion conditions is to open the oil valve 17 for a predetermined limited interval such that only a safe amount of unburned oil is projected into the combustion chamber 13 of the boiler 10 in case for some unknown reason there is failure to establish combustion. The opening of the oil valve for this predetermined limited interval *g* is accomplished by the joint action of the two timing cams O<sup>1</sup>, O<sup>2</sup>. Cam O<sup>1</sup> serves to close the energizing circuit for the operating electromagnet 18 of the oil valve at the end of inter-

val  $f$  and cam  $O^3$  operates to open this circuit at the end of the short limited interval  $g$ .

This is accomplished in the following manner: During the rotation of the cam shaft 41, the cam  $O^1$  is moved into engagement with the spring contact  $O^3$  and the cam  $O^2$  is moved into engagement with the spring contact  $O^4$ . Upon continued rotation of cam shaft 41 during the time preceding the end of interval  $f$ , cams  $O^1$  and  $O^2$  serve to move the spring contacts  $O^3$  and  $O^4$  downwardly without, however, bringing these contacts into engagement. At the end of interval  $f$ , the cam  $O^1$  disengages the contact  $O^3$  and the latter springs with a snap action into engagement with the contact  $O^4$ . At the end of interval  $g$ , cam  $O^2$  disengages the contact  $O^4$  and the latter spring out of engagement with contact  $O^3$ . Thus contacts  $O^3$  and  $O^4$  remain in engagement only for the predetermined limited interval  $g$ .

The oil valve energizing circuit is traced from conductor 3, which remains energized as before from supply line  $L^1$  through the bottom spring contact  $O^3$ , the snap contacts  $O^4$  and thence through directly the energizing winding of the valve operating electromagnet 18 to the supply line  $L^2$ . The electromagnet 18 immediately operates the oil valve 17 to admit oil under pressure through the atomizing nozzle 11 into the combustion chamber 13. Under normal conditions the atomized oil is immediately ignited by the spark between the ignition electrodes 12 thus establishing combustion in the boiler.

The flame detector 14 at once responds to the presence of combustion and starts to operate its control contact from the cold side to the hot side. Upon the initial movement of the flame detector contact from the cold-side, the energizing circuit of relay C is interrupted. Thereupon, contact  $C^1$  opens and contact  $C^2$  is reclosed.

Upon reclosure of contact  $C^2$ , the holding circuit for the oil valve operating electromagnet 18 is reestablished through the circuits previously traced as extending from the supply line  $L^1$  through the safety door switch contact 58, the low water cutoff switch 36, the conductor 1, the limit switch L, the conductor 2, the contact  $A^1$ , conductor 3, the contact  $B^1$ , conductor 4, the normally closed contact  $C^2$ , the electric heater 34 of the low water cutoff switch and thence through the energizing winding of the valve operating electromagnet 18 to the supply line  $L^2$ . It is important to note that the inclusion of the heater or resistor 34 in this holding circuit serves to prevent effective reenergization of the electromagnet 18 after a voltage failure. Due to the voltage drop in the resistor 34, the reenergization of electromagnet 18 is not sufficient to attract the armature thereof and reopen the oil valve. Hence after such a voltage failure, the only way the valve can be reopened is to fully reenergize the magnet 18 through the energizing circuit as previously described.

The reestablishment of the holding circuit for the oil valve operating electromagnet 18 provides an additional period for maintaining the oil valve open simultaneously with operation of the other elements of the oil burner mechanism after the limited combustion establishing period provided by the closure of cam contacts  $O^3$ ,  $O^4$  and the reopening thereof. These contacts are opened by operation of the cam  $O^2$  to move the lower contacts  $O^3$  away from the upper contacts  $O^4$  at the end of the predetermined limited combustion establishing period  $g$ . In this way the

oil valve is maintained open while the contacts of the flame detector 14 is moving from the cold side to the hot side as the flame detector continues to progressively respond to the presence of combustion in the combustion chamber 13. However, the movable contacts of the flame detector must reach the hot side before the expiration of the additional interval  $h$  during which the  $B^3$  cam contact is maintained closed. Since the flame detector 14 is of the quick acting type, it is able under normal operating conditions to move from the cold side during the interval  $g$  and reach the hot side before the end of the additional interval  $h$ .

As soon as the movable contact of the flame detector 14 reaches the hot side, an entirely new and independent energizing circuit for relay B is established. This circuit is traced from conductor 3 which remains energized as before through the movable contacts of the flame detector in the hot position, conductor 74, the contacts  $B^2$  which are closed upon initial closure of the relay B and the operating winding of relay B to the supply line  $L^2$ . The independent energizing circuit for the relay B just traced serves to insure continued operation of the oil burner motor and the oil valve opening independently.

This establishment of the independent energizing circuit for the relay B through the hot side of the flame detector contacts as just traced serve to continue operation of the oil burner motor with the oil valve opened independently of further operation of the timing control mechanism as long as combustion is maintained in the combustion chamber 13 and contact  $A^1$  remains closed. However, the timing control motor 42 continues to operate during the interval  $i$  at the end of which the ignition cam contact is open to deenergize the ignition transformer and at the end of the final interval  $j$  the cam contacts T open to deenergize the operating winding of the timing motor 42 with the timing shaft 41 and all of the timing cams thereon returned to the initial "start" position.

Upon operation of the oil burner long enough to cause the boiler 10 to supply sufficient heat to the room heating radiator system to satisfy the room thermostat 30, the room thermostat operates to close on contact S and stop further operation of the oil burner. Upon closure of contact S the operating winding of relay A is short circuited and thereby deenergized. Thereupon the contacts  $A^1$ ,  $A^2$  are open. Upon opening of contact  $A^1$  conductor 3 is disconnected from the supply line  $L^1$  and all elements of the oil burner mechanism and control are deenergized. At the same time, the opening of contact  $A^2$  disconnects the relay winding A from the mid-terminal  $R^1$  of the control transformer CT. The flame detector 14 quickly returns its movable contact 15 to the cold position in response to the absence of combustion in the combustion chamber 13. Thus the oil burner and control mechanism is in its initial condition ready for a new start whenever the room thermostat 30 again closes on contact R to run the oil burner.

The boiler water temperature thermostat 31 functions to mechanically close the contact  $A^1$  whenever the boiler water temperature falls below a predetermined value. At the same time the vacuum relief valve 37 is opened by thermostat 31. Exactly the same sequence of the starting control operations are accomplished upon mechanical closure of the contact  $A^1$  as previously described when  $A^1$  was closed by en-

energizing the operating winding of the relay A under the control of the room thermostat 30. In this case the boiler water thermostat 31 mechanically opens the contacts A<sup>1</sup> when the operation of the oil burner has been continued long enough to raise the boiler water temperature to the value at which the thermostat 31 is set to operate. As previously pointed out, water thermostat 31 permits the oil burner boiler to be operated in the summer time to supply all domestic hot water heating requirements under the control of the boiler water temperature thermostat 31. However, at any time, winter or summer, that the room temperature falls below the value at which the room thermostat is set to close the contacts R, the oil burner will automatically operate to supply heat to the house heating radiator system. The operation of the vacuum relief valve 37 by the boiler water temperature thermostat 31 effectively prevents a supply of heat in a vapor system to the house heating radiators when the oil burner is operated under the control of the domestic hot water control thermostat. It will be understood that the thermostat 31 may, if desired, be arranged to respond directly to the temperature of the water in the domestic hot water storage tank instead of the temperature of the water in the boiler.

When it is desired to shut down operation of the oil burner for any considerable length of time, the main supply lines L<sup>1</sup>, L<sup>2</sup> are disconnected from the source of power by means of a suitable disconnecting switch (not shown). This deenergizes all of the oil burner operating and control apparatus. During such a shutdown interval, ambient temperature changes may occur in combustion chamber 13 such that the contact 15 of the flame detector 14 may be moved from the cold position. Consequently, upon reenergizing lines L<sup>1</sup>, L<sup>2</sup>, relay C will remain deenergized and hence prevent starting the cycle of operation of the burner to establish combustion. In order to permit energization of relay C independently of the position of the flame detector contact 15, an auxiliary switch M is provided for shunting the cold contact of the flame detector 14. Thus upon closure of switch M relay C is energized and the normal cycle of operation previously described up to the end of interval g is accomplished. However, in case the switch M is maintained closed after the end of interval g, it will be impossible for the flame detector 14 to effect deenergization of the relay C so as to return the contact C<sup>2</sup> to the closed position and establish a holding circuit for the oil valve in the manner previously pointed out in case flame is established. Hence the oil valve holding circuit will remain open and the oil valve will close at the end of interval g. This cuts off the supply of oil and stops combustion in the furnace. However, upon release of the switch M after the interval g, the oil burner control mechanism will start a new cycle under normal conditions so that the next time combustion is established during the interval g, the flame detector 14 is capable of operating to deenergize the relay C and thus maintains combustion established thereafter. The switch M preferably is biased to the open position by means of a spring or other suitable means so that it cannot be left permanently in the closed position.

The improved control system and apparatus of the present invention automatically protects against the following dangerous or abnormal conditions.

If the oil fails to ignite during the limited period g during which the oil valve is opened by operation of the cams O<sup>1</sup>, O<sup>2</sup>, the flame detector contact will not leave the cold position and the oil valve will reclose at the end of period g. The oil burner motor 21 will continue to run until disconnected by opening of cam contact B<sup>3</sup> at the end of interval h which in turn opens the contact B<sup>1</sup>. The operation of the timing motor 42 continues to complete its cycle. In so doing the arm 80 which is carried by the cam shaft 41 engages with the upper tooth of the lockout ratchet member 81 to lift this member one notch. As long as the C relay remains energized due to the flame detector remaining in the cold position, the spring latch 82 serves to engage the first notch on the ratchet member 81 and maintain it in the advance position. As long as the contact A<sup>1</sup> is maintained closed by either the room thermostat or by the water thermostat 31, the cam motor 42 continues to operate and start a new cycle. If flame again fails to be established during the limited interval g, the arm 80 engages the next tooth on the lockout ratchet 81 and advances this member another notch. Upon completion of the third cycle, the lockout ratchet 81 is advanced to bring the finger 83 into engagement with the arm 84 extending from the contact C<sup>1</sup> so as to open this contact. Thereupon the energizing circuit for the timing motor 42 as previously traced is interrupted and the oil burner mechanism is rendered inoperative until the difficulty causing the failure of establishment of combustion is corrected.

In case combustion is established during either the second or the third attempt, the flame detector 14 moves from the cold position and thereby deenergizes the relay C. This disengages the locking pawl 82 from the ratchet member 81 and permits the latter to return to its initial position. It is evident that the lockout ratchet mechanism may be reset at any time by interrupting the main power circuit L<sup>1</sup>, L<sup>2</sup>.

Whenever the boiler pressure exceeds the value at which the pressure responsive device 35 is set to open the limit contact L, the conductor 3 is disconnected from supply line L<sup>1</sup>, thus deenergizing all parts of the oil burner mechanism and control. When normal boiler pressure conditions are restored, a new starting cycle will begin whenever the room thermostat 30 or water thermostat 31 calls for heat.

Should the boiler water level fall below a predetermined value, the contacts of the low water cutoff device 36 will be operated to disconnect the conductor 1 from the supply line L<sup>1</sup> and thereby deenergize all of the equipment.

In a normal starting cycle, if combustion should be established at any time before the interval g, as might occur due to a leaky oil valve, protection against continued operation of the oil burner mechanism is obtained as follows:

As soon as flame appears in the combustion chamber 13, the flame detector moves its contact from the cold side, thus deenergizing relay C. Thereupon contact C<sup>1</sup> is opened which in turn causes the timing motor 42 to be deenergized. The opening of contact C<sup>1</sup> also deenergizes relay B, thus allowing contact B<sup>1</sup> to open and stop operation of the oil burner motor 21. As a result combustion is extinguished and the flame detector 14 again moves its contact to the cold side. Thereupon relays C and B are again energized and the starting cycle is resumed at the point of inter-

ruption. If this occurs before cam contact F has opened, the process of momentarily establishing flame and operation of the flame detector to stop the oil burner mechanism in the manner just described will be repeated and the cycle will again be interrupted. However, as soon as the cam contact F has opened, as will eventually happen if it is not open at the first occurrence of premature combustion, the oil burner motor 21 will not start since the starting winding is disconnected. This permits the timing motor 42 to continue the timing cycle without the oil burner motor operating. Continuation of the cycle will advance the lockout ratchet mechanism one notch. During the second cycle flame detection due to a leaky oil valve will again cause an interruption of the cycle but will not reset the lockout mechanism because the second tooth of the lockout ratchet member 81 is in engagement with the actuating arm 80. The second cycle is completed in the same way as in the first. In case the oil valve has cleared itself of the dirt or other obstruction causing leaking during the second or third cycle, premature combustion prior to the interval *g* will not be obtained and the normal starting sequence will result. However, in case the oil valve continues to leak the control will automatically lock out after three unsuccessful cycles. In the normal starting cycle, the lockout ratchet member 81 is reset by deenergization of relay C only during the oil valve opening period *g* when the flame detector leaves the cold contact.

Beginning a starting cycle before the flame detector contact has reset to the cold side is prevented since the cam motor cannot start until contact C<sup>1</sup> closes and contact C<sup>1</sup> cannot close unless the flame detector is in the cold position.

If the starting cycle is interrupted by either voltage failure or by a change in setting of the water thermostat or room thermostat, the starting cycle will be successfully resumed at the point of interruption unless the interruption occurs after the cam contact F has opened. In this latter case a complete new starting cycle will follow the completion of the interrupted cycle.

While I have illustrated and described the improvements of the present invention embodied in a control adapted for steam or vapor oil fired boiler, it will be evident that substantially the same control may be applied to a hot water boiler. The only variations are that the low water cutoff is omitted and the pressure limit control 35 is replaced by a boiler water temperature limit control which functions to open the limit switch L in case the boiler water temperature reaches a dangerous value. In hot water systems, the heater of the low water cutoff device is replaced by a similar resistor which prevents reopening of the oil valve with the holding circuit energized upon a momentary voltage failure.

What I claim as new and desire to secure by Letters Patent in the United States is:

1. In combination with an oil burner having an electric oil and air supply motor and an electric igniter, of a normally closed electromagnetic oil valve for preventing combustion and having an energizing circuit for opening the valve and a holding circuit for maintaining the valve open, an electric motor driven timing switch mechanism for operating said motor and igniter for a predetermined period of time and for closing the said energizing circuit of said electromagnetic

oil valve for a limited period of time intermediate the period of operation of said motor and igniter, and combustion responsive switching means effective during absence of combustion to render said electric motor driven switch mechanism operative and effective upon establishment of combustion during said limited period of time for closing said holding circuit of the said electromagnetic oil valve and for maintaining said oil and air supply motor in operation independently of said timing switch mechanism.

2. In combination with an oil burner mechanism, of control means for operating the oil burner mechanism for a limited period to attempt to establish combustion, combustion responsive means having a movable control member operable from one position to another position upon establishment of combustion, and means controlled by said member for continuing operation of said oil burner after said limited period and having one element rendered effective upon the initial movement of said movable control member from said one position during said limited period to continue operation of said oil burner for an additional interval and another element rendered effective upon the final movement of said movable control member to said other position during said additional interval for continuing operation of said oil burner mechanism thereafter.

3. In combination, an oil burner having a plurality of elements operable to establish combustion, a portion only of said elements being operable to continue combustion thereafter, control means for effecting concurrent operation of said elements only for a predetermined limited period to attempt to establish combustion, means responsive to combustion, means rendered effective upon the initial response of said combustion responsive means to establishment of combustion during said predetermined period for thereafter maintaining simultaneous operation of said elements for an additional period, and means rendered effective upon response of said combustion responsive means to combustion during said additional period for maintaining said portion of said elements in operation to continue combustion thereafter.

4. In combination with an oil burner mechanism, of control means for operating the oil burner mechanism for a limited period to attempt to establish combustion, means responsive to combustion, means rendered effective upon the initial response of said combustion responsive means to establishment of combustion during said limited period for continuing operation of said oil burner after said period and means rendered effective upon response of said combustion responsive means to combustion after said period for stopping operation of said oil burner in response to failure of combustion.

5. In combination with a burner mechanism, of timing means for initiating operation of said burner mechanism and continuing operation thereof for a predetermined limited period to attempt to establish combustion, means responsive to combustion and having a movable control member operable from one position to another position in response to the presence of combustion and operable from said other position to said one position in response to absence of combustion, means rendered effective upon the initial movement of said movable control member from said one position in response to establishment of combustion during said prede-

terminated period for thereafter maintaining said burner mechanism in operation for an additional period, and means rendered effective upon movement of said movable control member to said other position within said additional period for thereafter maintaining said burner mechanism in operation and for stopping operation of said burner mechanism upon the initial movement of said member from said other position in response to failure of combustion.

6. In combination with a fuel burner having separately operable devices jointly controlling the supply of fuel, of a timing means to effect concurrent operation of said devices to supply fuel only for a limited period of time, cooperating control means responsive to establishment of combustion during said limited period for continuing operation of said devices to continue combustion only for an additional limited period of time, and cooperating control means dependent upon maintenance of combustion during said additional period and thereafter for continuing operation of said devices to continue combustion.

7. In combination with an oil burner mechanism, of timing control means for operating the oil burner mechanism for a limited period, a normally closed oil valve for preventing combustion, control means associated with said timing control means for opening said oil valve and maintaining said valve open only for a predetermined limited interval during the period of operation of said oil burner mechanism, means responsive to combustion, means rendered effective upon the initial response of said progressive means to establishment of combustion during said limited interval for maintaining said oil valve open for an additional interval during the period of operation of said oil burner mechanism, and means rendered effective upon response of said combustion responsive means to the continuance of combustion during said additional interval for maintaining said oil burner in operation and said valve open to continue combustion thereafter.

8. In combination with an oil burner having electric motor driven oil and air pumping means, of control means including a timing device for operating said pumping means for a limited period, a normally closed oil valve for preventing the supply of oil to the burner, control means associated with said timing device for opening said oil valve and maintaining said valve open only for a predetermined limited interval during said limited period of operation of said pumping means, combustion responsive means having a movable control member operable from one position to another position upon establishment of combustion and operable from said other position to said one position upon extinguishment of combustion, means rendered effective upon the initial movement of said movable control member from said one position during said predetermined limited interval to maintain said oil valve open for an additional interval during said limited period of operation of said pumping means, and means rendered effective upon the final movement of said movable control member to said other position during said additional interval for maintaining said pumping means in operation and said valve open after said period and for reclosing said valve upon the initial movement of said member from said other position in response to failure of combustion.

9. In combination with an electric motor oper-

ated oil burner mechanism, a control system including in circuit said mechanism, a main control switch closed in response to a demand for heat, a switching means including an electric motor driven timing mechanism for operating the oil burner mechanism at recurring intervals to attempt to establish combustion upon closure of said main switch, combustion responsive means having a movable switch member operable from one position to another position upon establishment of combustion to stop said timing mechanism and to continue operation of said oil burner mechanism thereafter and operable from said other position to said one position upon extinguishment of combustion, electroresponsive switching means normally dependent upon operation of said switch member to said one position for initiating operation of said electric motor driven timing mechanism, and a normally open manually operable switch for controlling said electroresponsive switching means to initiate operation of said electric motor driven timing mechanism independently of the position of said movable switch member.

10. In combination with an oil burner mechanism, of combustion responsive means having a movable control member operable from one position to another position upon establishment of combustion and operable from said other position to said one position upon extinguishment of combustion, control means for the oil burner mechanism including timing means normally dependent upon operation of said member to said one position for effecting operation of the oil burner mechanism at recurring intervals to attempt to establish combustion, an auxiliary control member operable from one position to a second position for effecting operation of said timing means independently of the position of said first member to attempt to establish combustion for an interval, and means dependent upon return of said auxiliary control member to said second position for continuing operation of said timing means after said interval.

11. In combination with an oil burner, of combustion responsive means having a movable control member operable from one position to another position upon establishment of combustion and operable from said other position to said one position upon extinguishment of combustion, control means for the oil burner including timing means normally dependent upon operation of said member to said one position for effecting operation of the oil burner for a limited period to attempt to establish combustion, an auxiliary movable control member operable from one position to a second position for initiating operation of the control means to attempt to establish combustion when said first control member is away from said one position, and means cooperating with said timing device and dependent upon return of said first member to said one position and return of said auxiliary control member to said one position for continuing operation of said oil burner mechanism when combustion is established in response to operation of said auxiliary control member.

12. In combination with an oil burner having electric motor operated means for supplying oil and a normally closed oil valve for preventing the supply of oil, of control means operable for starting and stopping operation of said electric motor driven means and having a timing device for opening said oil valve and maintaining said valve open only for a predetermined limited period dur-

ing operation of said first means and combustion responsive means for controlling operation of said control means to stop said electric motor operated means upon establishment of combustion due to leaking of said oil valve prior to said limited period.

13. In combination, an electrically operated oil burner mechanism including a plurality of separately operable elements for jointly establishing combustion, a plurality of automatically operable master control and safety switches, each operable in accordance with a predetermined condition pertinent to the oil burner, electrically operated timing cam switch mechanism having contacts operated in a predetermined sequence, an electromagnetic switch connected to be energized by one contact of said time switch and jointly controlling with other contacts of said time switch the energization of said separately operable elements of the burner mechanism in a predetermined sequence, and connections whereby said electrically operated timing switch mechanism is energized under the control of said plurality of automatically operable master control and safety switches to start combustion and said electromagnetic switch is maintained energized thereafter independently of said timing switch to continue combustion under the control of said plurality of automatically operable master control and safety switches.

14. In combination with an automatic burner having a plurality of electrically controlled elements jointly operable for establishing combustion, of means including a timing control switch mechanism having an electric driving motor controlled by said switch mechanism after a predetermined operation thereof from an initial position for insuring continued operation of said switch mechanism through a complete cycle to effect operation of said burner elements in a predetermined sequence providing a limited period of joint operation thereof, combustion responsive circuit controlling means, master circuit controlling means operating jointly with said combustion responsive means for energizing said electric motor to operate said switch mechanism from said initial position in response to predetermined conditions dependent upon the absence of combustion, and circuit connections controlled by said combustion responsive means for stopping said timing control means in said initial position when combustion is established and for maintaining a predetermined portion of said elements in operation to continue combustion thereafter.

15. In combination with an automatic burner mechanism, of timing control means operable from an initial position through a complete cycle for effecting operation of said burner mechanism to establish combustion, combustion responsive means, master control means operating jointly with said combustion responsive means for starting said timing control means to operate from said initial position in response to predetermined conditions dependent upon the absence of combustion, and means controlled by said combustion responsive means for stopping said timing control means in said initial position when combustion is established and means controlled by said combustion responsive means for maintaining said burner mechanism in operation to continue combustion thereafter.

16. In combination with an automatic burner mechanism, of means including a master control and a timing device operable by said master control from an initial position through a complete

cycle for starting the burner to attempt to establish combustion, combustion responsive means effective upon establishment of combustion to maintain the burner in operation to continue combustion thereafter independently of said timing device and a plurality of means for stopping said timing device in said initial position, one dependent upon establishment of combustion and another dependent upon failure to establish combustion.

17. In combination with a burner device having a plurality of electrically controlled elements jointly operable for establishing combustion, of means including a master control and an electric motor driven timing switch mechanism having the motor energized in an initial position under the control of said master control switch to operate the timing control switch mechanism from said initial position through a complete cycle for effecting operation of said elements in a predetermined timed sequence providing a limited period of joint operation thereof to establish combustion, combustion responsive means effective upon establishment of combustion to maintain a portion of said elements in operation to continue combustion thereafter independently of said timing switch mechanism, and a plurality of means for deenergizing said motor with said timing control switch mechanism in said initial position, one dependent upon establishment of combustion and another dependent upon failure to establish combustion.

18. In combination with an automatic burner having a plurality of electrically controlled elements jointly operable for establishing combustion, of means including a master control and an electric motor driven timing switch mechanism having the motor energized in an initial position under the control of said master control switch to operate the timing control switch mechanism from said initial position through a complete cycle for effecting operation of said elements in a predetermined timed sequence providing a limited period of joint operation thereof to establish combustion, combustion responsive means for maintaining a portion of said elements in operation to continue combustion independently of said timing switch mechanism upon establishment thereof, and a plurality of means for deenergizing said motor with said timing control switch mechanism in said initial position, one dependent upon failure to establish combustion during a predetermined number of cycles of operation of said timing switch mechanism and the other dependent upon establishment of combustion during said predetermined number of cycles.

19. The combination with a burner having a fuel supply means, an igniter and a normally closed fuel supply valve, of control means including a timing device for operating said fuel supply means and igniter for a predetermined interval and for opening said fuel supply valve and maintaining said valve open to establish combustion conditions only for a predetermined limited period during operation of said fuel supply means and igniter, and combustion responsive means effective upon establishment of combustion during said limited period to maintain said fuel supply means in operation and said fuel supply valve open independently of said timing device.

20. The combination with a burner having fuel supply means, means for igniting fuel supplied to the burner and separately operable means for controlling the supply of fuel from said fuel supply means to the burner, of means including

a timing device for rendering said fuel supply means and said igniting means operative for a predetermined interval of time and for effecting the operation of said fuel control means during a predetermined intermediate part of said predetermined interval to establish combustion conditions, and combustion responsive means effective upon establishment of combustion during said intermediate part of said interval for thereafter maintaining both said fuel supply means and said fuel control means operative to supply fuel to the burner independently of said timing device.

21. The combination with an oil burner having an electric motor driven oil and air pumping means, an electric igniter for the oil, and a normally closed electrically controlled oil valve for preventing the supply of oil from said pumping means to the burner, and automatic control means including a main control switch operable in response to predetermined conditions, and an electrically operated time switch mechanism controlled thereby for energizing said oil and air pumping means and said igniter for a limited period and for energizing said oil valve for a predetermined part of said limited period after said oil and air pump means and ignition means have been energized, and combustion responsive switching means effective upon establishment of combustion during said part of said limited period for maintaining said motor driven oil and air pumping means and said oil valve energized independently of said time switch mechanism.

22. The combination with a burner mechanism provided with means normally preventing combustion, electromagnetic means operative when energized for rendering said first means ineffective and having an energizing circuit and a holding circuit with a resistor therein for preventing reenergization of said electromagnetic means after a voltage failure, control means for operating said burner mechanism and having a timing circuit control means for closing said energizing circuit and maintaining said energizing circuit closed only for a limited period of time during the starting operation of said burner mechanism, and combustion responsive means effective upon establishment of combustion during said limited period for closing said holding circuit.

23. The combination with an oil burner having an electric motor driven oil supply pump and an igniter, of a normally closed electromagnetic oil valve for preventing the supply of oil to the burner and having an energizing circuit for opening the valve and a holding circuit for maintaining the valve open, a resistor in said holding circuit for preventing reopening of the valve after a temporary voltage failure, circuit controlling means for energizing said oil supply motor and igniter and having a timing circuit control means for closing said energizing circuit only for a limited period after the initial energization of said oil supply motor and igniter, and combustion responsive means effective upon establishment of combustion during said limited period for closing said holding circuit.

24. In combination with a burner mechanism operable to establish combustion, of combustion responsive means operable in response to both the presence and absence of combustion, control means normally dependent upon operation of said combustion responsive means in response to the absence of combustion for initiating operation of said burner mechanism, and an auxiliary control means for effecting operation of the first control

means to initiate operation of said burner mechanism upon failure of said combustion responsive means to respond to the absence of combustion.

25. In combination with a burner having fuel supply means and a normally closed valve for preventing the supply of fuel to the burner, of control means including a timing device for operating said fuel supply means and for opening said fuel valve and maintaining said valve open only for a predetermined limited period during operation of said first means, and means including a combustion responsive device for controlling said control means upon establishment of combustion due to leaking of said fuel valve prior to said limited period to prevent continued operation of said fuel supply means.

26. In combination with a burner having electrically operated fuel and air supply means and an electrically operated ignition means, of a control system therefor including an automatic control switch responsive to predetermined conditions controlled by the burner, an electromagnetic switch, an electric motor driven timing switch having a plurality of contacts operated in a predetermined timed sequence, a combustion responsive switch, and circuit connections whereby said electric motor driven timing switch is energized under the control of both said automatic control switch and said combustion responsive switch to operate one of its contacts to effect operation of said electromagnetic switch and other of its contacts to effect jointly with said electromagnetic switch operation of said fuel and air supply means and ignition means for overlapping definite time intervals to establish combustion and whereby both said combustion responsive switch and said automatic switch controls said electromagnetic switch independently of said timing switch to continue only operation of said fuel and air supply means after said intervals upon establishment of combustion until either combustion fails, said automatic switch operates or voltage fails.

27. In combination with an electrically operated oil burner having an igniter, an electromagnetic oil valve and a burner motor provided with a starting and a running winding, of an electromagnetic switch for controlling energization of said running winding, an electrically operated time switch having contacts operated in a predetermined sequence for controlling energization of said electro-responsive switch, said igniter, said oil valve, and said starting winding, a combustion responsive device, and means automatically responsive to a predetermined condition control by the burner cooperating with said combustion device for controlling the energization of said time switch to operate the burner to start combustion and for controlling energization of said electromagnetic switch independently of said time switch to maintain the running winding of said motor energized after combustion is established.

28. In combination with an oil burner having an igniter and a burner motor provided with a starting and a running winding, of a control system therefor including an electromagnetic switch connected to control the energization of said running winding, a motor driven time switch having sequentially operated contacts connected to control energization of said igniter, said starting winding, and said electromagnetic switch and having a separate contact connected to insure return of the time switch to its initial position, means including a combustion responsive switch effective in the absence of combustion for ener-

gizing the driving motor of said time switch to start operation of the burner and effective in the presence of combustion to maintain said electromagnetic switch energized independently of said time switch, and means preventing reenergization of said electromagnetic switch independently of said time switch after a voltage failure during the presence of combustion.

29. In combination with an oil burner having electrically controlled fuel supply means and an electrically controlled igniter, of an electrically operated timing switch mechanism having a separately operable electro-responsive switch energized thereby and cooperating therewith for controlling operation of said fuel supply means and igniter to attempt to establish combustion during a limited time interval, means including a com-

bustion responsive switch and a thermostatic switch for controlling said electrically controlled timing switch mechanism to energize said electrically controlled fuel supply means and igniter to establish combustion, connections whereby upon establishment of combustion said combustion responsive switch and said thermostatic switch maintain said electromagnetic switch energized to maintain said fuel supply means in operation independently of said timing switch means until either combustion falls, the thermostatic switch operates, or voltage fails, and means preventing reenergization of said electromagnetic switch independently of said timing switch mechanism after a voltage failure.

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