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[54] **CONTROL CIRCUIT FOR A HEATING SYSTEM**

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[51] **Int. Cl.** **F24d 1/02**
[58] **Field of Search** .... 237/9 R; 236/26 A, 236/21 R, 22, 40, 78, 91

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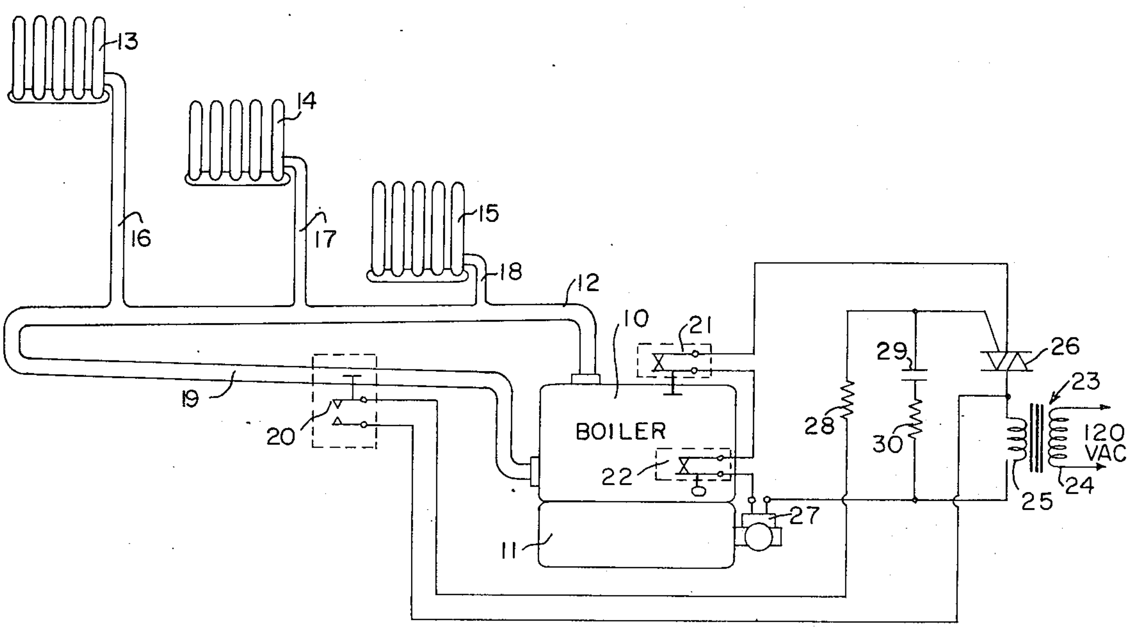
[57] **ABSTRACT**

A solid-state control circuit for a steam heating system of the type wherein a steam boiler is fired when the condensate returned to the boiler reaches a predetermined minimum temperature, and is shut down when the steam pressure developed in the boiler reaches a predetermined maximum level or when the water level in the boiler falls below a predetermined minimum level. Provision is made for preventing premature shutdown of the boiler from momentary low water conditions, and for positively shutting down the system under conditions of excessive steam pressure. The circuit utilizes a minimum number of components, and provides improved reliability and safety over prior-art relay-type circuits. A preferred mounting arrangement for the principal components of the circuit is also shown.

18 Claims, 3 Drawing Figures



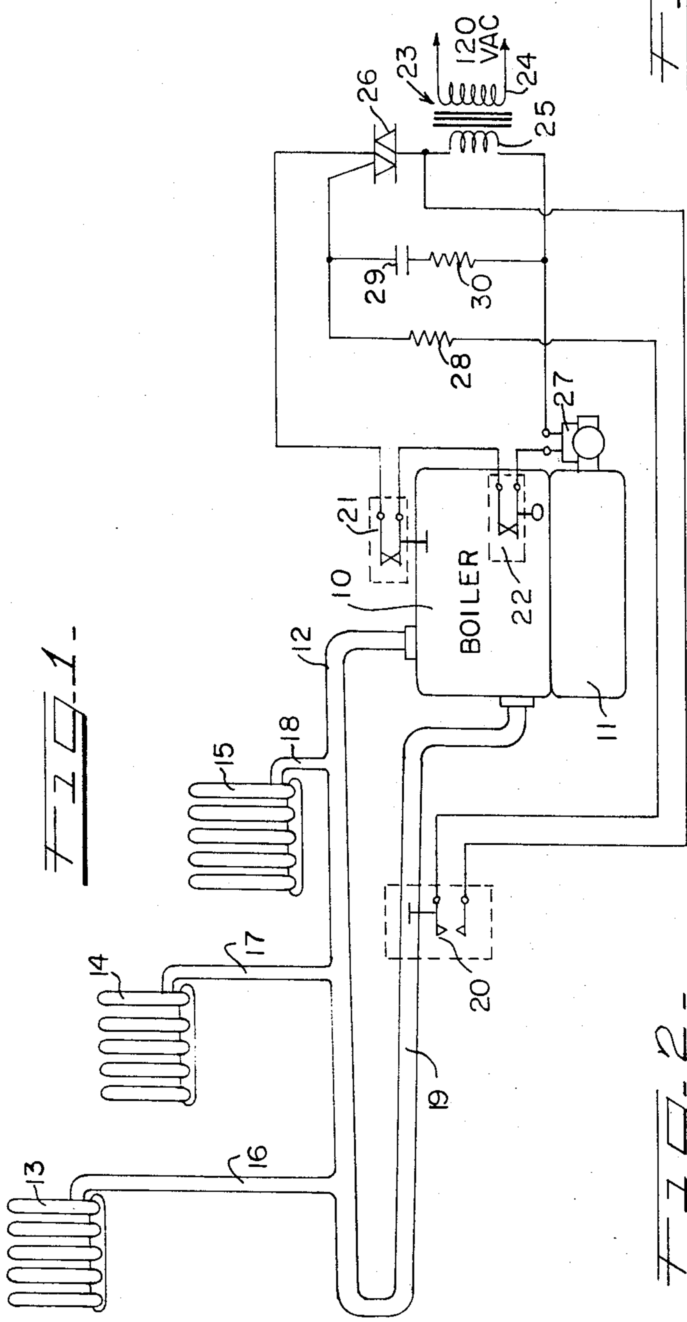


FIG. 1

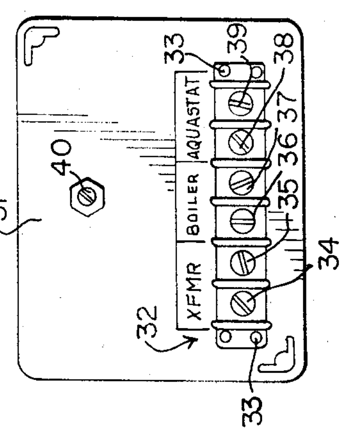


FIG. 2

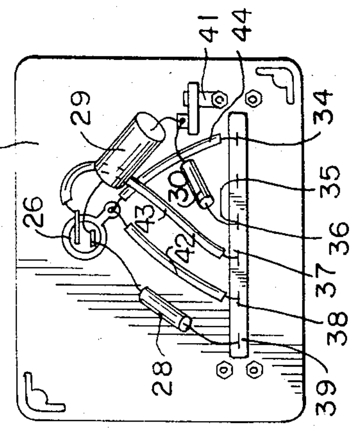


FIG. 3

CONTROL CIRCUIT FOR A HEATING SYSTEM

BACKGROUND OF THE INVENTION

This case pertains to control circuits, and more particularly to control circuits for steam heating systems.

In the operation of large steam heating systems, such as those employed in apartment buildings and factories, the boiler is fired when the condensate returned to the boiler from the radiators of the system falls to a predetermind minimin temperature. For optimum efficiency the boiler then continues to run until a predetermined maximum steam pressure is reached, at which time the boiler is shut down until the return condensate again falls to the predetermined minimum temperature. Operated in this manner, the system achieves maximum efficiency, since a minimum head of steam is maintained at all times within the boiler without a continuous comsumption of fuel.

Unfortunately, prior-art electrical control systems for achieving the above-described manner of operation in steam heating systems have heretofore been unduly complicated, unnecessarily adding to the complexity and expense of heating systems. Typically, such control systems have required two relays; one relay associated with the aquastat, a thermal switch mounted within the condensate return line and responsive to condensate temperature, and one relay associated with a boiler mounted steam pressure switch. The aquastat operated relay included a holding circuit which kept it energized so as to continuously operate the burner after being initially energized by the aquastat. The pressure switch operated relay was wired to open the holding circuit to de-energize the aquastat relay upon being energized by the steam reaching the predetermined maximum pressure.

Aside from complicating heating system control circuits, the use of multiple relays with individual control circuits has also adversely affected the reliability of heating systems. This is because the two relays, which were often operated in inaccessible, dusty, poorly ventilated environments, did not receive the periodic maintenance required for reliable operation. Furthermore, the prior-art systems sometimes presented a fire hazard, since the relay contacts in switching the highly inductive solenoid of the burner were subject to arcing during start-up and shut-down of the heating system.

Another problem associated with prior-art control circuits is that the furnace was subject to undesirable sporadic shut-downs from momentary low water conditions in the boiler. Such low water conditions, which may develop as a result of a sudden fluctuation in steam demand, resulted in the aquastat relay being de-energized, terminating operation of the burner before the predetermined boiler steam pressure has been reached and before the return condensate was cool enough to close the aquastat to initiate another boiler cycle. As a result, the heating cycle was prematurely terminated and further operation was impossible until the temperature of the return condensate fell to its minimum predetermined value.

Accordingly, it is an object of the present invention to provide a new and improved control system for a steam heating system.

It is a more specific object of the present invention to provide a new and improved control circuit for a steam heating system which requires fewer components and is more economical to construct.

It is a still more specific object of the present invention to provide an improved control circuit for a steam heating system which provides improved safety in not utilizing switching components susceptible to arcing.

It is a still more specific object of the present invention to provide a new and improved control circuit for a steam heating system which does not utilize relays and other electromechanical switching devices requiring periodic maintenance.

It is a still more specific object of the present invention to provide a control circuit for a steam heating system wherein the boiler is not subject to premature shutdown from transient low water conditions.

It is still another object of the present invention to provide a control circuit for a steam heating system which is compact and compatible with existing electrical wiring.

The invention is directed to a control circuit for a steam boiler wherein the boiler is fired when the condensate returned to the boiler falls below a predetermined minimum temperature, and is shut down when the steam pressure developed in the boiler reaches a predetermined maximum level. The circuit comprises a source of current, means including a solenoid for controlling the operation of the boiler, and means comprising a controlled switch device having main electrodes serially connected between the current source and the solenoid, and a gate electrode for initiating conduction between the main electrodes for supplying current to the solenoid. Means comprising a temperature sensing switch are further provided in the return line of the condensate for applying a current to the gate electrode to initiate conduction between the main electrodes to fire the boiler when the temperature of the condensate falls below a predetermined minimum level, and means comprising a pressure switch disposed between the source and the solenoid are provided for interrupting current to the solenoid to shut down the boiler when the steam pressure reaches the predetermined maximum level.

BRIEF DESCRIPTION OF THE DRAWINGS

The features of the present invention, which are believed to be novel, are set forth with particularity in the appended claims. The invention, together with the further objects and advantages thereof, may best be understood by referance to the following description taken in connection with the accompanying drawings, in the several figures of which like reference numerals identify like elements, and in which:

FIG. 1 is a schematic diagram, partly in functional block form, of a steam heating system and its associated control circuit constructed in accordance with the invention.

FIG. 2 is a front elevational view of a portion of the control circuit of the present invention.

FIG. 3 is a rear elevational view of a portion of the control circuit shown in FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, a steam heating system is shown which comprises a boiler **10** and an associated burner or stoker **11**. Boiler **10** and burner **11** may be entirely conventional in design and construction, the steam produced thereby being supplied to a steam distribution pipe **12** which distributes steam to the various radiators of the system. Specifically, in FIG. 1 three radiators 13, 14 and 15 are shown at various levels within a building. The steam rises up the individual header pipes 16, 17 and 18, respectively, of these radiators and releases energy in the form of heat as it condenses from a vapor state to a liquid state within the radiator. The resulting liquid condensate flows back down the individual header pipes and down the distribution pipe 12, returning to the boiler through a return line 19. It will be understood that additional radiators could be included in the system, the total number being limited only by the capacity of the boiler.

The manner of operation of steam heating plants is well known to the art, and accordingly only a brief description of its operation will be given here. To maintain steam pressure within distribution pipe 12, it is necessary to periodically fire the burner 11 of boiler 10. As we have previously mentioned, for maximum operating efficiency this is done on a cyclical basis, operation of burner 11 being initiated when the condensate in return line 19 falls to a predetermined minimum temperature. Once the burner has begun to operate, it continues to operate until the steam pressure developed in boiler 10 reaches a predetermined maximum value, typically in the order of 3 to 5 psi. This is notwithstanding that the condensate may rise above its predetermined minimum temperature in the interim.

To achieve this operating cycle with maximum reliability and safety and with a minimum number of components, the steam heating system of FIG. 1 incorporates a novel solid-state control circuit. To sense the temperature of the return condensate, this circuit includes an aquastat 20 installed on the condensate return line 19. This aquastat, which may be conventional in design and construction, basically comprises normally open switch contacts adjustable to close when a sensing element, disposed within line 19, senses that the liquid condensate has fallen to a predetermined minimum temperature within the range of 100° F. to 220° F. The exact temperature is determined by manual adjustment, and is normally set in the order of 160° F.

The system further includes a steam pressure cut-out switch 21, which is mounted on boiler 10 and which may also be conventional in design and construction. This switch comprises normally closed contacts which open when the steam pressure within the boiler exceeds a predetermined maximum pressure within the range of 3 to 5 psi, the exact pressure being set by manual adjustment. An additional cut-out switch 22 is provided in boiler 10 to sense the water level within the boiler. This switch comprises normally closed contacts which open when the water level within the boiler reaches a predetermined minimum level.

A power source in the form of a step-down transformer 23 is included in the control circuit. This transformer has a primary winding 24 coupled to the AC line and a secondary winding 25 on which a lower voltage current, preferably in the order of 24 volts, is developed. One terminal of this secondary winding is connected to one main electrode of a controlled solid-state switch device, Triac 26, and to one contact of aquastat 20. The other main electrode of Triac 26 is connected to one terminal of pressure cut-out switch 21. The remaining terminal of switch 21 is connected to one terminal of water level cut-out switch 22. The remaining terminal of switch 22 is connected to one terminal of a burner control solenoid 27, which controls the flow of fuel to burner 11 and hence the operation of boiler 10. The exact nature of this solenoid depends on the type of fuel used, which may be gas, oil or coal, depending on user preference and fuel availability. The remaining terminal of burner control solenoid 27 is connected to the remaining terminal of secondary winding 25. The remaining terminal of aquastat 20 is connected by a resistor 28 to the gate electrode of Triac 26, which is also connected to the ramaining terminal of secondary winding 25 by the series combination of a capacitor 29 and a resistor 30.

In operation, the primary winding of transformer 23 is connected to the AC line and a low-voltage AC current of approximately 24 volts is developed across secondary winding 25. Triac 26 is initially non-conductive so that no current flows through the circuit comprising Triac 26, switches 21 and 22, and burner control solenoid 27. Now, assuming the temperature of the condensate in return line 19 has fallen below the preset minimum temperature of aquastat 20, that switch closes and an AC current is applied to the gate or control electrode of Triac 26 by way of resistor 28 and the phase shift network of capacitor 29 and resistor 30. This renders the Triac conductive, enabling current to flow through normally closed switches 21 and 22 to the control solenoid 27 of burner 11, firing the burner and causing boiler 10 to produce steam for the heating system.

As the condensate temperature rises, aquastat 20 eventually opens, opening the current path to the gate electrode of Triac 26 through resistor 28. Triac 26 would now open if it were not for the phase shift circuit comprising capacitor 29 and resistor 30, which serve to maintain sufficient current flow through the gate electrode of Triac 26 to maintain conduction in that device. However, the maintaining current thus supplied to the gate electrode by capacitor 29 and resistor 30 is not sufficient in itself to initiate conduction in the Triac, a larger current being required to initiate conduction in the Triac than to sustain conduction once initiated. To achieve this result, the AC reactance of capacitor 28 in combination with the resistance of resistor 29 must be carefully selected.

Burner 11 continues to operate until the steam pressure in boiler 10 becomes sufficient to open the contacts of pressure switch 21. When this occurs the series circuit through Triac 26 is interrupted, terminating conduction in that device and hence de-energizing the burner control solenoid 27. This shuts down the boiler and the cycle is not repeated until the temperature of the condensate in return line 19 falls to the level where the contacts of aquastat 20 again close.

The water level switch 22 is provided within boiler 10 to prevent the boiler from being fired in the absence of sufficient water within the boiler, and to this end the normally closed contacts of the switch are connected in series with the burner control solenoid 27. However, we have seen that boilers are subject to transient low water conditions which may be expected to momentarily and unnecessarily open switch 22. To preclude this happening from prematurely terminating the operating cycle of the heating system, capacitor 29 and resistor 30 are selected to provide a time constant which will maintain the sustaining current on the gate of Triac 26 for a period greater than anticipated transient low water conditions. In practice, this period has been selected to be approximately **20** seconds. Thus, although current flow may be interrupted through traic **26** by momentary actuation of switch **22**, if switch **22** is closed within the time constant provided by capacitor **29** and resistor **30** conduction will again be established through Triac **26** and the boiler will again be fired. Should this feature not be desired, it can be defeated by connecting a relatively low impedance, in the order of 22,000 ohms, in shunt across the series combination of capacitor **29** and resistor **30.**

A preferred mounting arrangement for the principal components of the control circuit of the invention is shown in FIGS. **2** and **3.** There, the circuit has been incorporated on a flat plate **31**, approximately four inches square and appropriately notched to mount on a standard four inch square electrical junction box. This construction will in many instances greatly simplify installation, since the circuit can be merely fitted on an existing junction box with all but a few of the required interconnections already made. Referring to FIG. **2**, the assembly is seen to comprise a six-terminal barrier strip **32** fastened by means of machine screws or other appropriate fasteners **33** to one side of the cover plate **31.** The individual terminals **34–39** of the terminal strip are assigned to connect to various components of the boiler control system. Specifically, terminals **34** and **35** connect to transformer **23**, terminals **36** and **37** connect to switches **21** and **22** and burner control solenoid **27**, the terminals **38** and **39** connect to aquastat **20.** Thus, a minimum number of connections are required between the plate and external control circuit components, and those that are required can be made to the readily accessible terminal strip.

Referring now to FIG. **3** it is seen that the individual components of the control circuit can be conveniently interconnected on the reverse side of the mounting plate. Triac **26** is mounted to mounting plate **31** by means of an insulated mounting stud on to which a nut **40** or other fastener is threaded on the front side of the plate. While both main electrodes and the gate electrode of Triac **26** are electrically insulated from the mounting plate, the mounting arrangement nevertheless provides good thermal conductivity. The heat dissipated by the Triac is quickly conducted to the mounting plate which, because of its large surface area, provides an efficient heat sink. A terminal strip **41** is mounted beneath the plate by one of the machine screws used to mount barrier strip **32.** This terminal strip serves as a tie point between capacitor **29** and resistor **30.** The gate electrode of Triac **26** is connected to terminal **39** by resistor **28** and the main electrodes of Triac **26** are connected to terminals **38** and **37** by means of insulated conductors **42** and **43**, respectively. Terminals **36** and **35** are connected to tie point **41** by resistor **30**, and thence by capacitor **29** to the gate electrode of Triac **26.** Terminal **34** is connected to a main terminal of Triac **26** by an insulated con-ductor **44.**

The resulting control circuit assembly requires very little space and can be conveniently mounted on top of a standard electrical terminal box. Often this box will already exist within the boiler environment, and if not, it can be readily added. It will be appreciated that it would also be possible to incorporate transformer **23** into the assembly, perhaps by mounting it on the surface of plate **31.** This would eliminate the need for connections between the transformer and terminals **34** and **35**, but would necessitate providing for the connection of 120 volt AC line current to the primary winding **24** of transformer **23.**

Thus, a novel control circuit has been shown for a steam heating system which combines increased economy with increased reliability. The circuit requires fewer parts and fewer interconnections than prior-art control systems. It provides protection against transient interruptions of the operating cycle caused by momentary low water level conditions, while providing increased protection against excessive steam pressure and lack of water level. Of particular note is the use of capacitor **29** and resistor **30** to hold Triac **26** in conduction while at the same time providing a delay in deactivation of the Traic from transient conditions.

In practice, the General Electric (trade name) 41B13 selected-gate type Triac has been found to have sufficient disparity in initiating and sustaining gate current requirements for successful operation of the circuit. With this Triac, resistors **28** and **30** have been selected to be 470 ohm 1 watt units and capacitor **29** to be 1 microfarad for a 24 volt AC current supply.

While a particular embodiment of the invention has been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the invention in its broader aspects, and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of the invention.

We claim

1. A control circuit for a steam boiler wherein the boiler is fired when the condensate returned to the boiler falls below a predetermined minimum temperature, and is shut down when the steam pressure developed in the boiler reaches a predetermined maximum level, comprising:

a source of current;

means including a solenoid for controlling the operation of said boiler;

means comprising a controlled switch device having main electrodes serially connected between said current source and said solenoid, and a gate electrode for initiating conduction between said main electrodes;

means comprising a temperature sensing switch in the return line of said condensate for applying a current to said gate electrode to fire said boiler when the temperature of said condensate falls below said predetermined minimum level; and

means comprising a pressure switch disposed between said source and said solenoid for interrupting current to said solenoid to shut down said boiler when said steam pressure reaches said predetermined maximum level.

2. A control circuit as defined in claim **1** wherein said controlled switch device requires a minimum sustaining current through said gate electrode to maintain conduction through said main electrodes when the temperature of said condensate rises above said predetermined minimum level, and wherein conduction sustaining circuit means coupled between said source and said gate electrode are provided for supplying said sustaining current.

3. A control circuit as defined in claim **2** wherein said controlled rectifier requires a minimum initiating current for establishing conduction between said main electrodes, said initiating current being controlled by said temperature sensing switch, and wherein said minimum initiating current is greater than said minimum sustaining current.

4. A control circuit as defined in claim 3 wherein one main electrode of said controlled rectifier is coupled to one terminal of said source, the other main electrode of said controlled rectifier is coupled to one terminal of said solenoid, the remaining terminal of said solenoid is coupled to the remaining terminal of said source, and said gate electrode is coupled by said conduction sustaining circuit means to said source.

5. A control circuit as defined in claim 4 wherein said conduction sustaining circuit means comprise a serially connected resistor and capacitor, and wherein said gate electrode is further coupled by said temperature sensing switch to said source.

6. A control circuit as defined in claim 1 wherein said current source comprises an alternating current source and said controlled switch device comprises a Triac.

7. A control circuit as defined in claim 1 wherein the current through said main electrodes is subject to undesirable momentary interruptions, and said conduction sustaining circuit means has a time constant such that sustaining current continues to be supplied to said gate electrode during said momentary interruptions.

8. A control circuit for a steam boiler wherein the boiler is fired when the condensate returned to the boiler falls below a predetermined minimum temperature, and is shut down when the steam pressure developed in the boiler reaches a predetermined maximum level, comprising;

a source of current;

means including a solenoid for controlling the operation of said boiler;

means comprising a controlled switch device having main electrodes serially connected between said current source and said solenoid for supplying current to said solenoid, and a gate electrode for initiating conduction between said main electrodes, said control switch device requiring a first predetermined minimum gate current to sustain conduction through said main electrodes, and a second greater predetermined minimum gate current to initiate conduction through said main electrode;

means including a temperature sensing switch in the return line of said condensate for applying a current greater than said second predetermined gate current to said gate electrode to initiate conduction between said main electrodes to fire said boiler when the temperature of said condensate falls below said predetermined minimum level;

conduction sustaining circuit means for applying a current greater than said first predetermined gate current but less than said second predetermined gate current to said gate electrode to sustain conduction through said main electrodes after said boiler has fired and before said boiler has reached said predetermined maximum steam pressure; and

means comprising a pressure switch serially disposed between said current source and said solenoid for interrupting current to said solenoid to shut down said boiler when said steam pressure reaches said predetermined maximum level.

9. A control circuit as defined in claim 8 wherein said current source comprises an alternating current source, said controlled switch device comprises a Triac.

10. A control circuit as defined in claim 9 wherein said conduction sustaining means comprise a resistor and a capacitor.

11. A control circuit as defined in claim 8 wherein means comprising a liquid level switch are serially disposed between said current source and said solenoid for interrupting current to said solenoid to shut down said boiler when the water level in said boiler reaches a predetermined minimum level, said switch responding to momentary fluctuations in said water level by unnecessarily shutting down said boiler, and wherein said conduction sustaining means has a time constant sufficient to maintain said minimum sustaining current in said controlled switch device during said momentary fluctuations so that conduction can be reestablished thereafter through said main electrodes.

12. In a steam heating system of the type having a steam boiler, means including a solenoid for controlling the boiler, a source of current for said solenoid, a temperature sensing switch in the condensate return line to said boiler which closes when said condensate reaches a predetermined minimum temperature, and a pressure switch which opens when the steam pressure in said boiler reaches a predetermined maximum level, a control circuit comprising:

means comprising a controlled switch device having main electrodes and a gate electrode for initiating conduction between said main electrodes;

means for coupling said gate electrode through said temperature sensing switch to said source to initiate conduction in said controlled switch device when said condensate reaches said predetermined minimum temperature; and

means for coupling said main electrodes in series between said source, said pressure switch and said solenoid to fire said boiler when said return condensate reaches said predetermined minimum temperature, and to shut down said boiler when said steam pressure reaches said predetermined maximum level.

13. A control circuit as defined in claim 12 wherein said controlled switch device requires a minimum sustaining current through said gate electrode to maintain conduction through said main electrodes when the temperature of said condensate rises above said predetermined minimum level, and wherein conduction sustaining circuit means coupled between said source and said gate electrode are provided for supplying said sustaining current.

14. A control circuit as defined in claim 13 wherein said controlled rectifier requires a minimum initiating current for establishing conduction between said main electrodes, said initiating current being controlled by said temperature sensing switch, and wherein said minimum initiating current is greater than said minimum sustaining current.

15. A control circuit as defined in claim 14 wherein one main electrode of said controlled rectifier is coupled to one terminal of said source, the other main electrode of said controlled rectifier is coupled to one terminal of said solenoid, the remaining terminal of said solenoid is coupled to the remaining terminal of said source, and said gate electrode is coupled by said conduction sustaining circuit means to said source.

16. A control circuit as defined in claim 15 wherein said conduction sustaining circuit means comprise a serially connected resistor and capacitor, and wherein

said gate electrode is further coupled by said temperature sensing switch to said source.

17. A control circuit as defined in claim **12** wherein said current source comprises an alternating current source and said controlled switch device comprises a Triac.

18. A control circuit as defined in claim **12** wherein the current through said main electrodes is subject to undesirable momentary interruptions, and said conduction sustaining circuit means has a time constant such that sustaining current continues to be supplied to said gate electrode during said momentary interruptions.

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