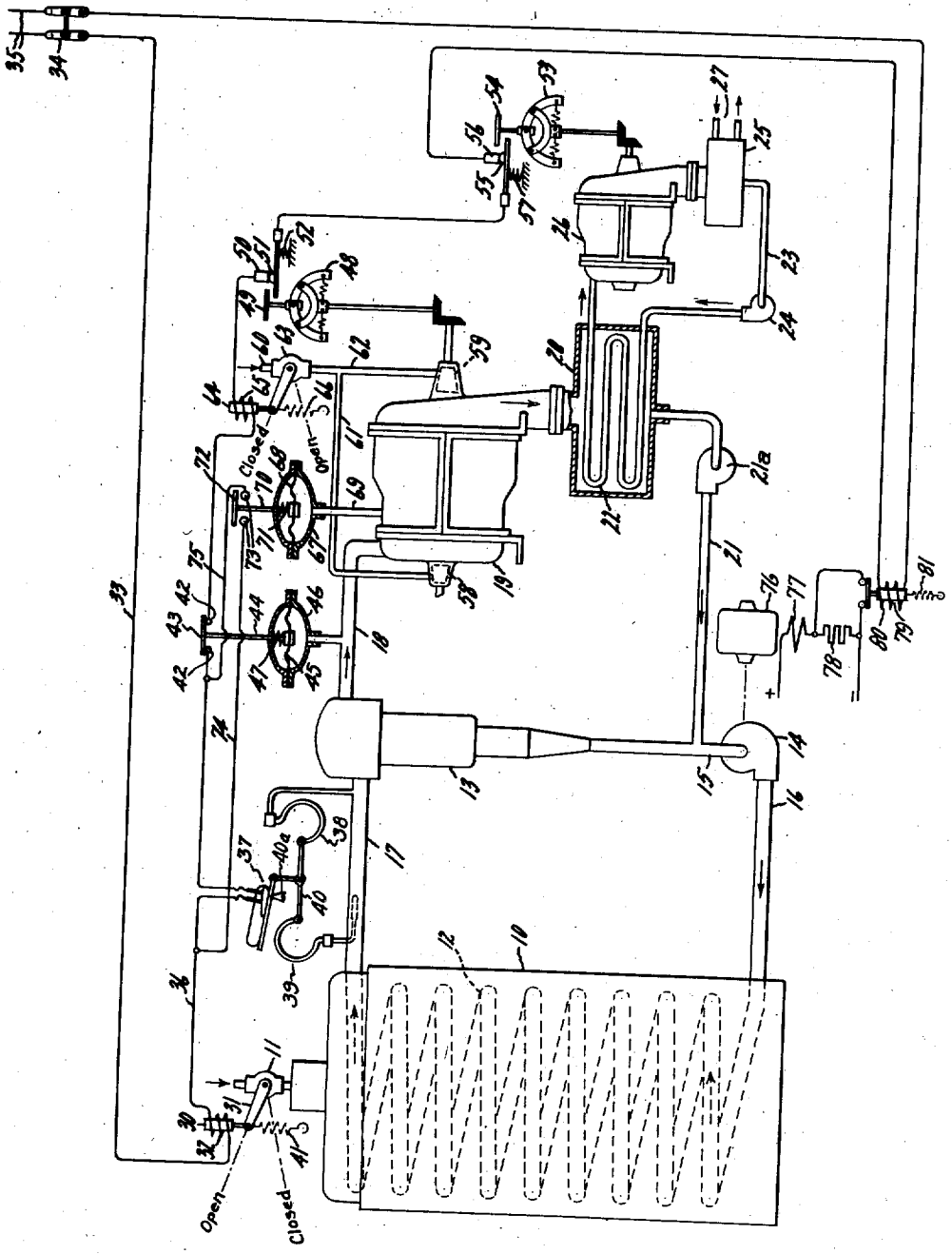
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ELASTIC FLUID POWER PLANT CONTROL AND PROTECTION

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ELASTIC FLUID POWER PLANT CONTROL AND PROTECTION

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8 Claims. (Cl. 60—105)

The present invention relates to elastic fluid power plant control and protection, that is, to a system for controlling and protecting various elements of an elastic fluid power plant in response to certain conditions to which such elements are subjected. More specifically the invention relates to the control of elastic fluid generators and turbines in response to changes in elastic fluid conditions, although it is not limited thereto necessarily. The invention is of particular significance in connection with forced circulation and flash boilers in which liquid is heated in heating elements and discharged into a drum or vessel at reduced pressure to be converted at least partly into vapor. In boilers of this type it becomes desirable to prevent evaporation of liquid within the heating elements, particularly during high load conditions because the conversion of liquid into vapor within the heating elements reduces considerably the permissible heat transfer to such heating elements and consequently the load output of the boilers.

The general object of my invention is to provide an improved construction and arrangement of elastic fluid power plant control and protection whereby safe maximum load output may be maintained under varying conditions.

For a consideration of what I believe to be novel and my invention, attention is directed to the following description and the claims appended thereto in connection with the accompanying drawing.

The single figure of the drawing illustrates a diagrammatic view of an elastic fluid power plant embodying my invention.

The power plant shown in the present instance is a binary fluid plant consisting of a mercury fluid circuit and a steam circuit linked, in known manner, by a condenser boiler. The mercury fluid circuit comprises a boiler 10 to which fuel is supplied for maintaining combustion by means including a valve 11. The boiler has a heating element 12 which has a lower end receiving mercury liquid from a drum or vapor liquid separating device 13 by means of a pump 14 having an inlet 15 connected to the device 13 and a discharge 16 connected to the lower end of the heating element 12. The device 13 is fully disclosed in the application of Bigger and Hargrove Serial No. 91,946 filed at the same date and assigned to the same assignee as the present application. Liquid forced through the heating element 12 is discharged at the upper end thereof and conducted by a conduit 17 to the liquid vapor separating device 13. The liquid is recirculated from the device 13 through the heating element 12 and the vapor is conducted from the device 13 through a conduit 18 to a mercury vapor turbine 19, whence the vapor is discharged into a condenser 20 to be condensed therein. The condensate is conducted from the condenser 20 by a conduit 21 and a pump 21a to the inlet 15 of the circulating pump 14. The elements so far described form what is known as the mercury vapor circuit. The condenser 20 includes a cooling element 22, in the present instance shown diagrammatically as a coil which has an inlet connected by a conduit 23 including a pump 24 to a source of cooling medium, in the present instance shown as a steam condenser 25. Water is forced from the condenser 25 by the pump 24 through the cooling element 22 in which the water is evaporated to be discharged to a steam turbine 26. The turbine exhausts into the condenser 25. The latter has an inlet 27 for conducting cooling medium to the condenser to effect condensation therein. The circuit including the coil 22, the turbine 26 and the condenser 25 forms the steam circuit. The condenser 20 which serves to effect condensation of the mercury vapor discharged from the turbine 19 and heating and evaporation of the water flowing through the coil 22 is termed a condenser boiler. It forms the link between the mercury and the steam circuit.

As stated above, in forced circulation and flash type boilers it is desirable, particularly during high load conditions, to prevent evaporation of liquid within the heating element in order to permit maximum heat transfer to the heating element. Evaporation of liquid may be due to either one or a combination of two conditions. Evaporation is effected if at constant pressure of a liquid its temperature rises beyond a certain value, and evaporation is also effected if at constant temperature of a liquid its pressure is reduced below a certain value. The pressures and temperatures at such certain values are known as saturation pressures and temperatures respectively. For example, at a temperature of 1,126° F. the saturation pressure of mercury is 358 lbs. per square inch. At this pressure and temperature the mercury liquid is converted into vapor. In order to prevent evaporation at 1,126° it is therefore desirable to subject the mercury to a slightly higher pressure, for instance, to 380 lbs. per square inch. In other words, it is desirable to maintain a pressure differential of 22 lbs. per square inch. This pressure differential of 22 lbs. per square inch at the same time produces a temperature differential of 12° F. because at a pres-

sure of 380 lbs. per square inch absolute the saturation temperature of mercury is 1,138° F. which is 12° above 1,126°. Thus, if mercury is normally heated to a temperature of 1,126° at a pressure of 380 lbs. per square inch absolute the mercury is in liquid form. Evaporation will take place only if the pressure is reduced by at least 22 lbs. per square inch absolute, or if the temperature is increased by 12° F., or if both values of pressure and temperature vary accordingly.

In accordance with my invention, an elastic fluid power plant is provided with means for controlling the aforementioned pressure and temperature differentials or, from another viewpoint, to prevent evaporation of the operating liquid, for instance mercury, as in the present case, within the heating element or elements of the boiler. In a preferred embodiment these means include a device responsive to pressure and temperature differentials of the operating liquid and means associated with the fuel supply for the boiler and in cooperative relation with the pressure and temperature differential responsive device to shut off the fuel supply whenever the temperature or pressure differential or both drop below fixed values. Thus, the supply of fuel to the boiler to maintain combustion therein is controlled in response to pressure and temperature conditions of the operating liquid discharged from the heating elements. These pressure and temperature conditions depend upon several variables and in many cases it is desirable to control the fuel supply in response to changes of these and other variables. One of these variables is the speed of a prime mover, for instance, a turbine receiving fluid from the boiler. As the speed rises to a certain value or emergency speed, it is desirable to shut down the turbine and simultaneously the boiler. Another of these variables is the pressure of the elastic fluid conducted to the turbine. Whenever this pressure rises beyond a certain maximum value, it is desirable to shut off the fuel supply to the boiler.

Referring now more specifically to the arrangement shown in the drawing, the fuel supply valve **11** during normal operating condition is held in open position by means of an electromagnet having a core **30** connected to an arm **31** of the valve and a coil **32** forming a part of an electric circuit with one end of the coil **32** connected by a conductor **33** and a switch **34** to a source of electric energy **35** and the other end of the coil connected by another conductor **36** to the source **35**. The electric circuit includes a plurality of contacts or switches which are opened and closed in response to certain changes of operating conditions. A pair of contacts, in the present instance forming a part of a mercury switch **37**, is controlled by a temperature pressure differential responsive device which has been indicated diagrammatically as including a pressure-responsive element **38** in the form of a Bourdon tube and a temperature-responsive element **39** also in the form of a Bourdon tube. The pressure-responsive element **38** has an open lower end portion communicating with the discharge conduit **17** of the heating element **12**. The free ends of the Bourdon tubes are connected by a floating lever **40** which has an intermediate point pivotally connected to the mercury switch **37**. The latter is supported on a fulcrum **40a**.

During operation the switch **37** is normally closed. An increase in temperature at constant pressure of the fluid in conduit **17** causes upward movement of the left-hand end of the floating lever **40**, thus moving the switch towards opening position. Similarly, a decrease in pressure at constant temperature causes upward movement of the right-hand end of the lever **40** and turning of the switch **37** towards opening position. A decrease in pressure and a corresponding simultaneous decrease in temperature causes counterclockwise turning of the lever **40** about its intermediate pivotal connection to the switch without affecting the latter. The temperature-responsive element **39** has a sealed end portion disposed within the conduit **17**. The Bourdon tube **39** contains the same liquid as the boiler, in the present instance mercury. If the pressure of the fluid drops a certain value, which heretofore I termed a pressure differential, for instance 22 lbs. per square inch, the switch **37** is opened, assuming that the temperature remained constant. Similarly, if under constant pressure conditions the temperature drops a certain value, heretofore termed temperature differential, for instance 12° F. as in the above example, the electric circuit is also opened. Opening of the circuit causes closing of the fuel supply valve **11** by the action of a spring **41**, biasing the valve arm **31** towards closing position. In the preferred embodiment, as shown, the temperature pressure differential responsive device (**37** to **40**) is connected to the discharge conduit **17** of the heating element **12**, that is, ahead of the drum **13**. A pair of contacts **42** connected in series with the switch **37** is controlled in response to changes of the pressure of the fluid conducted to the turbine. The contacts **42** are normally closed by a contact-making member **43** secured to a stem **44** which is connected to a diaphragm **45** of a pressure-responsive device **46**. The lower side of the diaphragm **45** is subjected to the fluid pressure in the turbine inlet conduit **18** and the upper side of the diaphragm **45** is biased downward by a spring **47**. The arrangement is such that the contact-making member **43** is moved upward against the force of the spring **47** to open the circuit as the fluid pressure in the turbine inlet conduit **18** reaches a certain maximum value. Opening of the contacts **42**, like opening of the switch **37**, interrupts the circuit for the coil **32** and thus causes closing of the fuel supply valve **11** by the action of the spring **41**.

As pointed out above, it is desirable to shut down the boiler, that is, to close the fuel supply valve **11** if the turbine speed reaches a certain emergency value. In the usual power plant arrangement, turbines are provided with emergency speed governors and valves actuated by the speed governors for shutting down the turbine in response to a certain maximum speed. In the present instance the power plant includes two turbines **19** and **26** and both turbines are provided with means for effecting closing of the fuel supply valve **11** in response to certain speed conditions. The turbine **19** has an emergency speed governor **48** driven from the turbine shaft and provided with a switch operating member **49**. The electric circuit includes contacts or switch members **50** and **51**, the latter being normally biased towards the contact **50** by the action of a compression spring **52**. As the speed of the turbine rises and reaches emergency speed, the governor flyweights by the action of centrifugal force move outward and thus cause downward movement of the member **49** until the latter finally opens the contacts **50, 51**. Similarly, the turbine **26** is provided with a centrifugal type emergency speed governor **53** driven from the

turbine shaft and including a switch operating member 54. The member 54 is in cooperative relation with a contact or switch member 55 normally biased towards a contact 56 by the action of a compression spring 57. If the speed of the steam turbine 26 reaches a certain maximum value, the centrifugal weights of the governor are forced outward and in a certain position effect opening of the contacts 55, 56, the contact 55 being forced downward against the action of the compression spring 57. Opening of either contacts 50, 51 or 55, 56 interrupts the electric circuit, deenergizing the coil 32 and resulting in closing of the fuel supply valve 11 of the boiler.

An important problem in elastic fluid power plants is the sealing of certain elements normally subjected to pressures below atmosphere to prevent leakage of air into such element. One such element is the elastic fluid turbine. The sealing of the turbine shaft against the casing is especially important in mercury power plants, that is, where turbines are operated by mercury vapor because air leaking into the turbine may be conducted therefrom to the boiler and cause oxidation therein of the boiler walls and the mercury. The leakage of air into the turbine may be overcome by the provision of sealing means forming chambers around the shaft to which an inert or non-oxidizing gas, for instance nitrogen, is supplied at a pressure slightly above atmosphere. In the present instance the turbine 19 has sealing chambers 58 and 59 to which nitrogen or other gas is supplied at a pressure slightly above atmosphere by means including a conduit 60 having branches 61 and 62 connected to the chambers 58 and 59 respectively. The conduit 60 receives gas from a suitable source, not shown, and includes a valve 63 which is closed during operation and opened when the turbine is shut down. In accordance with my invention the valve 63 is normally held in closed position by an electromagnet having a core 64 and an energizing coil 65 connected in series with the aforementioned contacts. If one of the contacts is opened, the electric circuit is interrupted and consequently the coil 65 is deenergized, resulting in opening of the valve 63 by the action of a spring 66.

Thus, with the arrangement described above, the fuel supply valve 11 is closed and the nitrogen supply valve 63 is opened in response to first, a certain increase in temperature of the fluid discharged from the heating element 12 to the drum 13; second, a certain decrease in pressure of the fluid discharged from the heating element 12; third, a combination of the causes mentioned under number one and two; fourth, a certain increase in pressure of the fluid conducted to the elastic fluid turbine 19; and fifth, a certain increase in speed of either turbine 19 or turbine 26.

In many cases there is no objection to the evaporation of fluid within the heating element or elements during light load conditions. To meet such a situation, means are provided for rendering the temperature pressure differential responsive device (38 to 40) inoperative or rather ineffective as the load on the turbine reaches a certain low value, for instance one-third load. The means for accomplishing this in the present example is a load-responsive device in the form of a pressure-responsive device having a casing 67 divided into two halves by a diaphragm 68. The lower half, that is, the space below the diaphragm communicates by a pipe 69 with the high pressure end, preferably the first stage shell, of the turbine 19. Thus, the diaphragm 68 is subjected to the first stage shell pressure of the turbine 19, which pressure is substantially proportional to the load output of the turbine. The diaphragm carries a stem 70 and is biased in downward direction by a spring 71 surrounding the stem. A contact-making member 72 is secured to the upper end of the stem and arranged in cooperative relation with two contacts 73 connected by conductors 74 and 75 to the terminals of the temperature pressure differential responsive device (38 to 40) so as to bridge the switch 37 whenever the contacts 73 are closed. A decrease in load of the turbine 19 causes a decrease in the first stage shell pressure whereby the diaphragm 68 is forced downward by the action of the spring 71 until finally a certain pressure corresponding to a certain low load is reached when the contact-making member 72 bridges the contacts 73 and thus short-circuits the switch 37. When this occurs, opening of the switch 37 no longer interrupts the electric circuit, the temperature pressure differential responsive device then being ineffective or short-circuited and vapor may be produced within the heating coil 12.

Another important feature of my invention is the provision of means for controlling the circulation of fluid through the heating coil 12 in response to fluid conditions in the discharge conduit 17. It is desirable to increase the amount of fluid forced through the coil, that is, to increase the velocity of fluid within the coil, in response to increasing temperature at constant pressure and in response to decreasing pressure at constant temperature, that is, in response to a condition which normally would cause the fluid to evaporate within the heating coil. To this end the circulating pump 14 for forcing liquid into the heating coil 12 is driven by a variable speed motor 76, in the present instance shown as a direct current motor having a field 77 with a resistance 78 connected in series with the field 77. The resistance 78 is normally short-circuited by means of a relay 79 having a coil 80 connected in series with the aforementioned electric circuit including the switch 37 operated by the pressure-temperature differential responsive device. When the switch 37 opens, the electric circuit is interrupted and the coil 80 deenergized, causing opening of the relay by the action of a spring 81 whereby the flow of current through the field coil 77 is reduced due to the increase in resistance and consequently the speed of the motor 76 is increased, causing an increase in speed of the pump 14 with the resulting increased flow of liquid through the heating coil 12.

Having described the method of operation of my invention, together with the apparatus which I now consider to represent the best embodiment thereof, I desire to have it understood that the apparatus shown is only illustrative and that the invention may be carried out by other means.

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

1. An elastic fluid power plant including the combination of a boiler having an element for receiving and heating liquid, a conduit including a valve for conducting fuel to the boiler, means for controlling the valve, and means for closing the valve to prevent pressure and temperature differentials of the heated liquid from dropping below certain values in order to prevent evaporation of liquid within the heating element.

2. An elastic fluid power plant including the combination of a boiler having a heating element for receiving liquid to be heated, a pressure and

temperature differential responsive device having elements subject to the pressure and the temperature of the liquid discharged from the heating element, fuel supply means for the boiler, and means including said device for controlling the fuel supply means.

3. An elastic fluid power plant including the combination of a boiler having a heating element, means for conducting liquid to the heating element, a drum for receiving liquid from the heating element and converting liquid into vapor, a conduit including a valve for conducting fuel to the boiler to maintain combustion therein, and a device responsive to pressure and temperature differentials of the fluid discharged from the heating element for closing said valve when the pressure and temperature differentials of the fluid reach certain minimum values.

4. An elastic fluid power plant including the combination of a boiler, an elastic fluid turbine having an inlet conduit connected to the boiler, a conduit including a valve for conducting fuel to the boiler, means including an electromagnet having an energizing coil and an electric circuit including a pair of normally closed contacts for energizing the coil to maintain the valve open, and a device responsive to the pressure of the elastic fluid conducted to the turbine for opening said contacts when the pressure of the fluid rises beyond a certain value.

5. An elastic fluid power plant including the combination of a boiler having a heating element for receiving and heating liquid, a liquid vapor separating drum connected to the element for receiving heated liquid therefrom and converting it into vapor, a conduit including a valve for conducting fuel to the boiler, an electric circuit including an electromagnet normally to maintain the valve open, means including a pair of contacts in said circuit and a device responsive to pressure and temperature differentials of the liquid discharged from the heating element to effect opening of said contacts and interrupting of the circuit when the pressure and temperature differentials of the liquid discharged from the heating element drop below a certain minimum value, and means responsive to load output of the boiler for rendering said device inoperative when the load output drops below a certain value.

6. An elastic fluid power plant including the combination of a boiler having a heating element, means for conducting liquid to the heating element, a liquid vapor separating drum for receiving heated liquid from said element and converting it into vapor, an elastic fluid turbine having an inlet connected to the drum, a conduit including a valve for conducting fuel to the boiler to maintain combustion therein, means biasing the valve towards closing position, other means including an electric circuit with a plurality of pairs of contacts normally to hold the valve in open position, means including one pair of contacts to open the circuit when the pressure and temperature differentials of the fluid discharged from the heating elements reach certain minimum values, means including another pair of contacts for opening said circuits when the pressure of the fluid conducted to the turbine rises beyond a certain maximum value, means including another pair of contacts for opening said circuit when the speed of the turbine rises beyond a certain value, and means for sealing the turbine shaft against the casing when the turbine operation is interrupted comprising sealing chambers associated with the turbine shaft, a conduit including a valve for conducting gas to said chambers and means including an electromagnet having a coil connected in series with said circuit normally to maintain said valve closed and a spring to effect opening of said valve when said circuit is interrupted.

7. An elastic fluid power plant including the combination of a boiler having an element for receiving a heating liquid, means for forcing liquid through the element, means for receiving heated liquid from the element, and means for controlling the flow of liquid through the element in response to pressure temperature differential conditions of the heated liquid discharged from the element.

8. An elastic fluid power plant including the combination of a heating element having an inlet conduit and a discharge conduit, means including a pump connected to the inlet conduit for forcing liquid through the heating element, a motor for driving the pump, and means including a pressure temperature differential responsive device connected to the discharge conduit for controlling the speed of the motor.

EDWARD S. THOMPSON.

DISCLAIMER

2,088,623.—*Edward S. Thompson*, Schenectady, N. Y. ELASTIC FLUID POWER PLANT CONTROL AND PROTECTION. Patent dated August 3, 1937. Disclaimer filed March 22, 1938, by the assignee, *General Electric Company*.

Hereby disclaims claim 4 of said Letters Patent.

[*Official Gazette April 19, 1938.*]

temperature differential responsive device having elements subject to the pressure and the temperature of the liquid discharged from the heating element, fuel supply means for the boiler, and means including said device for controlling the fuel supply means.

3. An elastic fluid power plant including the combination of a boiler having a heating element, means for conducting liquid to the heating element, a drum for receiving liquid from the heating element and converting liquid into vapor, a conduit including a valve for conducting fuel to the boiler to maintain combustion therein, and a device responsive to pressure and temperature differentials of the fluid discharged from the heating element for closing said valve when the pressure and temperature differentials of the fluid reach certain minimum values.

4. An elastic fluid power plant including the combination of a boiler, an elastic fluid turbine having an inlet conduit connected to the boiler, a conduit including a valve for conducting fuel to the boiler, means including an electromagnet having an energizing coil and an electric circuit including a pair of normally closed contacts for energizing the coil to maintain the valve open, and a device responsive to the pressure of the elastic fluid conducted to the turbine for opening said contacts when the pressure of the fluid rises beyond a certain value.

5. An elastic fluid power plant including the combination of a boiler having a heating element for receiving and heating liquid, a liquid vapor separating drum connected to the element for receiving heated liquid therefrom and converting it into vapor, a conduit including a valve for conducting fuel to the boiler, an electric circuit including an electromagnet normally to maintain the valve open, means including a pair of contacts in said circuit and a device responsive to pressure and temperature differentials of the liquid discharged from the heating element to effect opening of said contacts and interrupting of the circuit when the pressure and temperature differentials of the liquid discharged from the heating element drop below a certain minimum value, and means responsive to load output of the boiler for rendering said device inoperative when the load output drops below a certain value.

6. An elastic fluid power plant including the combination of a boiler having a heating element, means for conducting liquid to the heating element, a liquid vapor separating drum for receiving heated liquid from said element and converting it into vapor, an elastic fluid turbine having an inlet connected to the drum, a conduit including a valve for conducting fuel to the boiler to maintain combustion therein, means biasing the valve towards closing position, other means including an electric circuit with a plurality of pairs of contacts normally to hold the valve in open position, means including one pair of contacts to open the circuit when the pressure and temperature differentials of the fluid discharged from the heating elements reach certain minimum values, means including another pair of contacts for opening said circuits when the pressure of the fluid conducted to the turbine rises beyond a certain maximum value, means including another pair of contacts for opening said circuit when the speed of the turbine rises beyond a certain value, and means for sealing the turbine shaft against the casing when the turbine operation is interrupted comprising sealing chambers associated with the turbine shaft, a conduit including a valve for conducting gas to said chambers and means including an electromagnet having a coil connected in series with said circuit normally to maintain said valve closed and a spring to effect opening of said valve when said circuit is interrupted.

7. An elastic fluid power plant including the combination of a boiler having an element for receiving a heating liquid, means for forcing liquid through the element, means for receiving heated liquid from the element, and means for controlling the flow of liquid through the element in response to pressure temperature differential conditions of the heated liquid discharged from the element.

8. An elastic fluid power plant including the combination of a heating element having an inlet conduit and a discharge conduit, means including a pump connected to the inlet conduit for forcing liquid through the heating element, a motor for driving the pump, and means including a pressure temperature differential responsive device connected to the discharge conduit for controlling the speed of the motor.

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