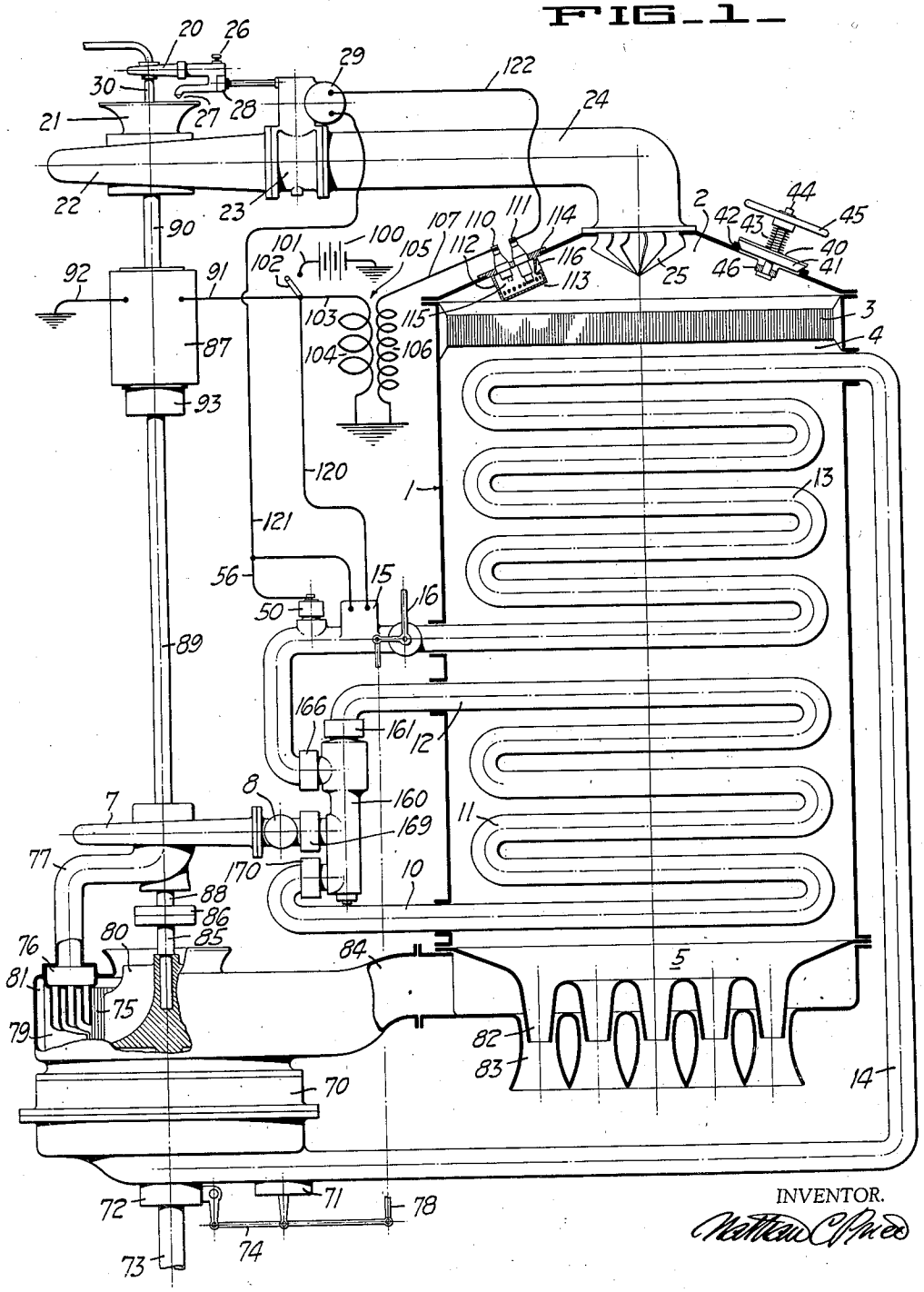
Jan. 25, 1938. N. C. PRICE 2,106,414

CONTROL SYSTEM

Filed March 5, 1935 2 Sheets-Sheet 1

FIG. 1



INVENTOR.

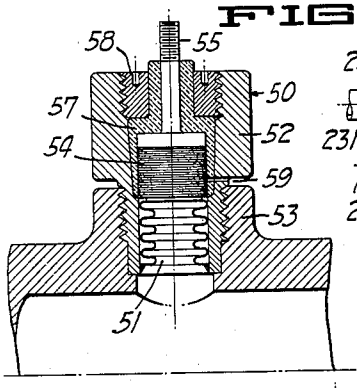
Matthew C. Price

Jan. 25, 1938. N. C. PRICE 2,106,414

CONTROL SYSTEM

Filed March 5, 1935 2 Sheets-Sheet 2

FIG_3_



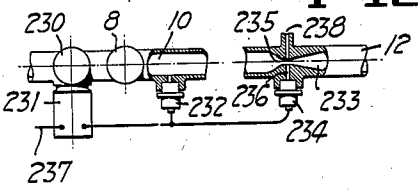
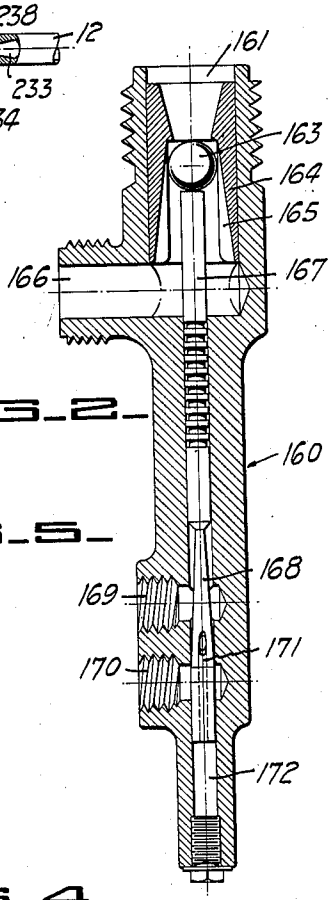


FIG_7_



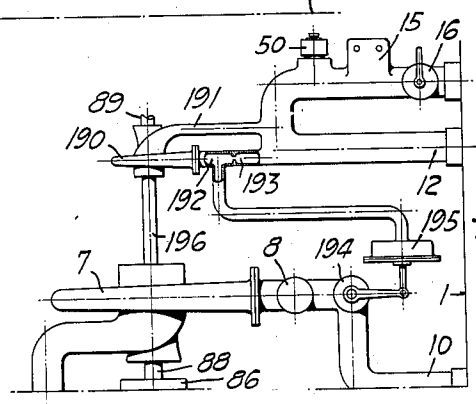


FIG_2_

FIG_5_

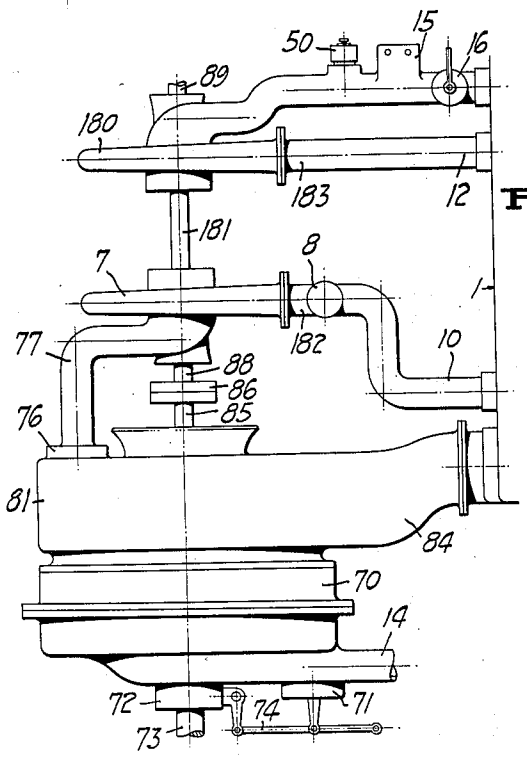


FIG_4_

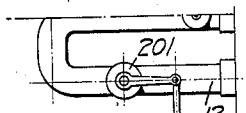
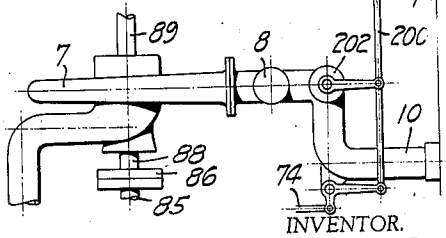


FIG_6_



INVENTOR.

Matthew C. Price

Patented Jan. 25, 1938 2,106,414

UNITED STATES PATENT OFFICE

2,106,414

CONTROL SYSTEM

Nathan C. Price, Berkeley, Calif.

Application March 5, 1935, Serial No. 9,368

22 Claims. (Cl. 122—448)

My invention relates to a new method of stabilization of forced circulation boilers in order that the temperature and the pressure of the superheated vapor discharged therefrom may be held constant, and that the fluid conditions within the boiler tube from the feed inlet to the vapor discharge outlet may be maintained continuously at the most advantageous values of pressure and temperature. It is applicable to boilers using water or other liquids.

My invention has particular value as a feedwater regulation system for series tube forced circulation boilers in moving vehicles, wherein high rates of fluid flow are employed.

In my co-pending applications, Serial No. 743,701 filed September 12, 1934, and Serial No. 691,682 filed September 30, 1933, I have described in detail the necessity for special feedwater control in order to make these boilers stable in action and capable of rapid change of steam output in accordance with power unit load demands. It is desirable to avoid setting up irregular cycles of pressure and temperature fluctuation, which result in destruction to the boiler tubing, and frequent inability of the boiler to answer load demands.

I have found that if the evaporation zone be kept within certain space limits in a series tube boiler, approximately constant outlet temperature and pressure will result.

For structural reasons, and in order to reduce the weight, space requirements, and expense of manufacture, the use of drums or large containers at the evaporation zone in order to permit maintenance of a definite water level is definitely undesirable. Furthermore such storage space represents a hazard in case of collision. The steaming up period is greatly lengthened and the boiler is not adaptable to rapid changes in load.

It is therefore the immediate object of my invention to fix the position of the evaporation region in a series tube boiler.

The ultimate aim of my invention is to regulate the boiler in such manner that approximately constant boiler outlet temperature and pressure will result.

For the protection of the boiler tubing and in order to obtain the highest possible boiler efficiency, it is the object of my invention to provide a regulation which is continuous in action. By the same token the system is required to attain stabilization without employing sudden cooling means in heated portions of the boiler.

From the standpoint of satisfactory operation in moving vehicles, it is the object of my invention to provide a boiler control which is virtually unaffected by angular position or accelerations of the vehicle, in any direction.

The foregoing and other objects are attained in the embodiments of my invention illustrated in the drawings, in which:

Figure 1 is a schematic diagram of a steam powerplant provided with the control system of my invention.

Figure 2 represents a cross sectional view of a device used in my control system for regulating the flow of feedwater into the boiler.

Figure 3 represents a cross sectional view of a pressure responsive device which may be used with the control system of my invention.

Figure 4 is a schematic diagram of a modified form of my invention for boiler control.

Figure 5 represents another modification of my invention for boiler control.

Figure 6 is an illustration of another modification, of my invention for boiler control.

Figure 7 represents a further modification of my invention for boiler control.

My invention employs means sensitive to the flow and the energy absorbing and delivering capabilities of the fluid in the evaporation zone of the boiler to regulate the feedwater supply, with or without a means sensitive to the flow of the liquid in the boiler economizer section to modify the action of the first means.

As an example of the operation of this system, a case is presented wherein feedwater at a pressure of 150 atmospheres and a temperature of 300° Fahr. is pumped into the inlet end of a long heated tube of a certain diameter. Superheated steam at 100 atmospheres pressures and 1000° Fahr. temperature is discharged from the outlet end of the tube, 50 atmospheres of pressure drop from the inlet to the outlet being required to produce the particular rate of flow. Between the ends of the tube an evaporation zone exists, the length of the evaporation zone measured along the boiler tube being approximately equal to one tenth of the tube length from inlet to outlet. The region of commencement of the evaporation zone is at a point in the boiler tube length wherein the pressure is 140 atmospheres, and the region of termination of the evaporation zone is at a point in the length of the tube wherein the pressure is 135 atmospheres.

Accordingly in the exemplary case the boiler fluid velocities at the tube inlet, commencement of evaporation zone, termination of evaporation zone, and the tube outlet, are in the ratio of 1.00, 1.55, 10.9, and 31.0, consecutively. Therefore, if

a device sensitive to kinetic (velocity) effects were placed in the boiler tube at the normal beginning of the evaporation zone it would ordinarily be subject to fluid having a velocity represented by 1.55. If conditions were to change thereby displacing the whole evaporation zone toward the inlet of the tube so that the terminus of the evaporation zone would be located where its beginning had been originally, then the terminal velocity represented by 10.9 would be effective on the kinetic device. Thus, due to this change in evaporation zone location in the tube by one tenth of the tube length there is made available an actuating force varying in magnitude approximately in the ratio of 10.9 to 1.55 or 7 to 1.

Steam below the critical pressure has a much greater volume than water at the same temperature and pressure. Consequently if a freely movable object is placed in a series boiler tube of a uniform size through which there is a steady flow, the object will be pushed harder and further if it is in the part of the tube containing steam than it would be if it were in the part of the tube containing water.

This effect is preferably utilized in controlling a forced circulation boiler as shown in Figure 1, in which a boiler casing (1) encloses a primary combustion chamber (2) and a porous refractory plate (3) through which the products of primary combustion filter to a secondary combustion chamber (4) where combustion is completed. The products of combustion then pass through a boiler economizer section (11) to a flue gas collection chamber (5).

The combustible mixture which is delivered into the boiler is formed by the discharge of a liquid hydrocarbon fuel from a centrifugal fuel pump (20) into an air intake bell (21) of a centrifugal air blower (22). The mixture so formed is driven past a damper (23), along a duct (24) to a spud of vanes (25) which impart a tangential motion to the mixture as it enters the primary combustion chamber.

The air to fuel mixture ratio is maintained at a constant value due to the similar discharge variations of the centrifugal air blower (22) and the centrifugal fuel pump (20) the rotors of which are interconnected by a shaft (30) for common speed of rotation. A manually adjustable fuel metering screw (26) is provided at the fuel pump discharge nozzle (27). Also a fuel discharge throttling valve (28) is placed adjacent to the metering screw. This throttling valve is linked to the damper so that both will always have the same relative degree of opening at all times. In this manner partial closure of the damper will not disturb the constancy of the air to fuel ratio. The fuel discharge throttling valve and damper are regulated by an electrical mechanism (29).

For the protection of the boiler casing in case of explosion in the combustion chamber due to delayed ignition, a combustion chamber pressure relief valve (40) is provided. Explosive pressures force a lid (41) off a bevelled seat (42) with a consequent release of pressure to the atmosphere. The raising of the lid from its seat is resisted by a spring (43). Concentric with the spring and passing through the lid is a threaded rod (44) upon which a turnwheel (45) is screwed for regulation of the spring pressure. The threaded rod is affixed to a support member (46) which together with the seat is built into the casing (1) of the boiler. The lid may be removed for inspection of the interior of the boiler.

The boiler fluid course comprises a boiler check valve (8), feed water inlet (10), an economizer section (11), an evaporation zone section (12), a superheater section (13), and a boiler steam outlet duct (14). Located in the evaporation zone section (12) are a temperature responsive device (15), a pressure responsive device (50), the feed water control mechanism (160) of my invention, and a manual shutdown throttle (16).

The pressure responsive device (50) is illustrated in Figure 3. It consists in its preferred form of a metal bellows (51) welded to a threaded body (52) which is screwed into a boss (53) in the wall of the boiler tube. The interior of the bellows communicates directly with the boiler fluid pressure which tends to expand the bellows axially, thereby exerting pressure upon an electrical resistance element (54). The characteristic of this element is that increase of pressure upon it will increase its electrical conductivity. Accordingly current admitted to a binding post (55) passes through the resistance element (54) and is grounded out in the bellows in relation to the pressure existing in the boiler tube. Surrounding the binding post and the resistance element is an insulator (57) held into the body (52) by a lock collar (58). A passage (59) through the body admits atmospheric pressure to the outside of the bellows.

The steam from the superheater section (13) progresses along the boiler outlet duct tube (14) to a turbine nozzle control (71) which determines how many nozzles the steam shall enter in passing through the turbine (70). The turbine nozzle control is regulated by a turbine speed governor (72) mounted on a main power driveshaft (73). A linkage (74) transmits the governor motion to the turbine nozzle control. A control link (78) is provided between the governor nozzle control and the manual shutdown throttle for disabling the governor action at will.

After expansion in the turbine the steam enters a condenser core (75) and upon becoming liquefied wholly or in part, passes into a collection chamber (76), from which a feed water pump (7) withdraws fluid along a conduit (77).

The condenser core (75) consists of some hollow cambered plates (79) placed in a ring about the periphery of a condenser blower rotor (80) in a tangential direction, thereby forming appropriate diffuser vanes. The steam to be condensed passes through the interior of the plates (79) in a direction at right angles to the condenser blower discharge air passing on the outside of the plates (79).

During light power plant loads the condenser blower rotor (80) which is driven directly by the turbine (70) is able to pump enough cooling air past the condenser core into a blower scroll (81) to cause proper condensation in the plates.

During heavy power plant loads the flow of the air past the condenser core is augmented by the production of a partial vacuum in the blower scroll, through utilization of waste energy in the combustion gases issuing from the boiler. This is performed by the discharge of flue gas through the flue gas nozzles (82) into the throats of the venturis (83) which are connected to the blower scroll by means of an air conduit (84). Thus the kinetic energy of the flue gases is used to draw cooling medium through the condenser.

During normal operation of the power plant, the steam turbine (70) drives the remaining boiler auxiliaries through a shaft (85) and an overrunning clutch (86). However, at the first part

of the steaming up period the steam turbine (70) is stationary and the overrunning clutch then permits an electric motor (87) to drive the auxiliaries without rotating the turbine and the condenser blower rotor.

In a preferred arrangement as illustrated in Figure 1, the shaft (88) connects the overrunning clutch to the feed water pump (7), a shaft (89) connects the feed water pump to the electric motor (87), a shaft (90) connects the electric motor to the blower (22) and a shaft (30) connects the blower to the fuel pump (20), in rotative relationship.

The action of the various units of the power plant on steaming up from cold is as follows:

The closure of an electric switch (102) causes current to flow along a lead (101) from a grounded storage battery (100) to three separate electrical circuits.

In the first electrical circuit the current passes along a lead (103) to a primary coil (104) of a transformer (105), from which it is grounded. The high tension current from the grounded secondary coil (106) of the transformer progresses along a lead (107) to a spark plug (110) where it produces sparking, for fuel mixture ignition.

In the second electrical circuit the current passes along a lead (91) to energize the electric motor (87) and cause the rotation of the various auxiliaries. The current is grounded through a lead (92). A motor speed governor (93) abruptly changes the excitation of the motor as it increases in speed due to the load of the auxiliaries being taken up by the steam turbine through the overrunning clutch. The electric motor is thereby immediately converted into a constant voltage electric generator.

In the third electrical circuit the current travels along a lead (120) to the temperature responsive device (15) which varies the current flowing in accordance with temperature within the tube.

From the device (15) the current is divided into two paths, one to the pressure responsive device (50) by way of the lead (56) and the other to the electric mechanism (29) for controlling the damper (23) and the fuel pump throttle (28).

The pressure responsive device (50) allows a large amount of current to be grounded out from the lead (121) when the pressure at the evaporation zone is high, and a negligible amount of current to be grounded out when the pressure is low.

The current which passes through the electric mechanism (29) causes simultaneous opening up of the damper (23) and the fuel throttling valve (28), and then passes along the lead (122) to the glow plug (111).

Since the conductivity of the device (15) is increased at low temperature, and the conductivity of the pressure responsive device is decreased by lowering of the boiler pressure, either insufficient temperature or lack of pressure in the boiler will serve to bring a greater amount of current to the electric mechanism (29) and increase the intensity of the boiler fire.

During the steaming up, a condition is sometimes experienced with moderately high temperature and very low pressure in the boiler tube as a result of initial shortage of liquid in the economizer section, whereupon the device (15) tends to shut down the fire, greatly prolonging the steaming up period, although the boiler tubing is not in danger.

Therefore, the glow plug (111) is used to exert an electrical influence upon the third circuit such that with a low boiler combustion chamber fire, and relatively cool combustion chamber conditions, the fire will not be easily shut off. A powerful fire on the other hand will allow the resistance element of the glow plug (111) to remain at a higher temperature with consequent increase of resistance and the greater tendency for the fire to be reduced thereby.

The fuel ignition assembly (112) mounted in the end of the boiler casing (1) projects into the primary combustion chamber (2). A perforated housing (113) is attached to the inner side of a mounting plate (114) enclosing a chamber (115). Screwed into the mounting plate are the spark plug (110) for ignition of combustibles by means of an electric spark, and the glow plug (111). The vaporization of fuel particles inside the perforated housing by the heat of the glow plug makes the ignition of the fuel by the spark plug more certain. A fuel spray deflector (116) directs mixture to the glow plug (111).

The feed water regulating mechanism (160) of the control system of my invention as revealed in Figure 1, throttles the discharge of the centrifugal feed water pump (7) to bring about the proper rate of flow to the boiler inlet.

Since the feed water pump is driven at constant speed by the governed steam turbine (70), an essentially constant pressure is available for feeding to the boiler inlet over a considerable range of flows.

The feed water flow may be stopped entirely through the full closure of the feed water regulating mechanism (160) or through the shutting down of the power plant so that the feed water pump would not be in motion. The feed water pump is not in operation when steam is not leaving the boiler to drive the steam turbine, unless the electric motor is driving the auxiliaries during the steaming up period.

Upon the initial subjection of the boiler tubing to the blast of hot gases of combustion, steam is formed in the economizer section (11) of the tubing. Referring to Figure 2, it is seen that a ball (163) of the evaporation zone valve (160) is forced along a conical duct (164) in order to admit the passage of the compressed steam from the inlet (161) through the guide lands (165) to an outlet (166). The displacement of the ball (163) by the steam moves a thrust rod (167) axially until a taper (168) admits a flow of feed water from a water inlet (169) to an outlet (170). A counter force is established acting along the thrust rod axis tending to restore the ball (163) to its seated position, as a result of the fluid flow friction pressure drop in the economizer section of the boiler and acting across the cross sectional area of the thrust rod. A passage (171) admits boiler inlet pressure to a chamber (172) adjacent the end of the taper (168).

If the economizer section of the boiler tubing has become filled with boiler liquid, the volumetric flow and the available kinetic energy at the terminus of the liquid column tending to force the ball (163) out of the conical duct (164) is small. Consequently the ball is returned part way to its seat and the feedwater flow is reduced.

A recession of the liquid column terminus subjects the ball (163) to the action of steam with its much greater volumetric flow. The impounded pressure in the convection region then forces the ball off its seat along the conical duct and the feed water flow is increased. Eventually a position of equilibrium is reached by the rod with the force resulting from liquid flow in the con-

vection bank tending to cause closure of the evaporation zone valve. This force of closure is balanced off by the impounded pressure and the impact pressure attempting to open the evaporation valve more as it rides on the end of the gradual boundary of the end of the saturated liquid.

The length of the liquid column in the boiler tubing is thus appropriately controlled and the boiler operates with temperature gradients and an outlet temperature of desired value.

In Figure 4, a modification of my boiler control system is illustrated and may be used with the arrangement of elements shown in Figure 1, except that the feed water regulating mechanism now consists of a pump (180) located at the evaporation zone of the boiler and working in direct opposition to the feed water pump (7) in order to build up a pressure in the economizer section (11) of the boiler. This pressure is used to control the discharge of the feed water pump (7) so that the portion of the boiler between the feed water pump and the evaporation zone pump (180) will be kept full of liquid.

The feed water pump (7) and the evaporation zone pump (180) are driven together and interconnected by the shaft (181). They are both rotated by the electric motor (87) or by the steam turbine (70) through the overrunning clutch (86). The discharge duct (182) of the feed water pump is connected to the inlet end of the boiler economizer section, and the discharge duct (183) of the evaporation zone pump is directed in opposition to the flow from the boiler economizer section (11). The inlet of the evaporation zone pump is connected to the inlet of the boiler superheater.

A tendency of the boiler liquid to pass beyond the evaporation zone pump into the superheater of the boiler results in a relatively great pressure being built up in the economizer section, because the evaporation zone pump is delivering kinetic energy to a liquid of high absorptive powers. The absorption of this kinetic energy produces kinetic pressure acting to limit the discharge of the feed water pump.

However, if steam is present at the evaporation zone, the evaporation zone pump will impart but a small amount of kinetic energy to the boiler fluid with small resultant pressure being built up in the boiler economizer section, and the feed water supply will then be unlimited by this device.

The external appearance of a diagrammatic representation of another modification of my invention is the same as in Figure 4, which will be used for its explanation.

The evaporation zone pump (180) of Figure 4 is now to be considered as an auxiliary turbine (180) which is in the path of flow of the boiler fluid at the evaporation zone and which receives kinetic energy from the evaporation zone fluid.

The size of the feed water pump (7) is reduced so that when it is driven at the governed speed of the turbine (70) it is unable to supply feed water to the boiler inlet unless the boiler pressure is far below its normal value.

If liquid is present at the evaporation zone of the boiler it imparts but a small amount of kinetic energy to the auxiliary turbine (180). At this time, the speed of the feed water pump will then depend upon the speed of the turbine (70) or the electric motor (87) and the consequent feed water supply to the boiler inlet will be a minimum.

However, if steam is flowing at the evaporation zone of the boiler, relatively great kinetic energy will be delivered to the auxiliary turbine (180) which will then rotate the auxiliaries at a speed far greater than that of the turbine (70). The increased speed of the feed water pump will result in a high discharge pressure and a great flow of water into the boiler inlet.

This modification of my invention keeps the economizer section of the boiler filled with liquid but does not allow liquid to pass the normal position of the evaporation zone.

In Figure 5 is presented an illustration of another modified form of my invention to be used with the arrangement of elements shown in Figure 1 except that the feed water regulating device now consists of a pump (190) located at the evaporation zone of the boiler and driven together with the feed water pump.

The inlet (191) of the pump (190) is taken from the boiler tube at the normal position of the evaporation zone. This pump discharges into a conduit (192) building up a pressure therein which is a summation of the boiler pressure at the evaporation zone plus the pressure produced due to the kinetic energy absorbed by the fluid passing through the pump (190). A duct (193) permits flow of a small amount of fluid from the conduit (192) back into the evaporation zone. A boiler feed water control valve (194) is operated by a pressure diaphragm (195) which is subject to the pressure in the conduit (192).

When there is liquid at the evaporation zone the centrifugal pump (190) delivers much kinetic energy to the boiler fluid and a high impact pressure is produced in the conduit (192) which added to the boiler evaporation zone pressure acts through the pressure diaphragm (195) to close the valve (194) and stop the flow of feed water to the boiler inlet.

However, when steam is at the normal position of the evaporation zone the pump is unable to deliver a great amount of kinetic energy to it and the pressure in the conduit is relatively low. This results in minimum deflection of the pressure diaphragm and a consequent large flow of feed water into the boiler.

Thus by the kinetic energy absorptive qualities of the boiler fluid at the normal position of the evaporation zone, liquid is kept within the required boundaries in the boiler tube.

In Figure 6 a further modification of my invention is disclosed. The various elements of the powerplant in Figure 1 remain the same as shown except for the feedwater regulation device which is herewith described.

A linkage (200) can be attached to the turbine nozzle control (71) (Figure 4) to control a throttling valve (201) at the normal position of the evaporation zone (12) and a throttling valve (202) at the feedwater inlet (10). All of these valves are opened simultaneously by the governor when the speed of the turbine (70) drops. However the nozzle control (71) is provided with a relatively great rate of opening, so that during light loads the evaporation zone throttle (201) is causing a pronounced throttling effect.

If steam exists at the normal position of the evaporation zone a greater amount of kinetic energy is being imparted to the boiler fluid with a given opening of the evaporation zone throttle (201) and with a given mass flow than if water were present at this zone. Thus a recession of the terminus of the fluid column in the boiler re-

sults in greater kinetic energy at the evaporation zone throttle (201) and a consequent drop in the superheater pressure due to the pressure drop across the evaporation zone throttle. This drop in the superheater pressure tends to cause speed reduction in the turbine. The speed governor then opens the evaporation zone throttle (201) to prevent the turbine speed from being further reduced. This causes the simultaneous opening of the feedwater throttle (202) with a consequent increase in the flow of feedwater into the boiler inlet and a restoration of the terminus of the liquid column to the evaporation zone throttle.

Upon the arrival of the liquid at the evaporation zone throttle (201) the kinetic energy of the fluid passing the throttle becomes greatly reduced such that the pressure drop across the evaporation zone throttle is negligible and the boiler superheater pressure becomes excessive. It is then the function of the turbine speed governor to shut down the valves to prevent the turbine speed from running too high. This reduces the feedwater flow and the boiler liquid is returned to its proper limits.

It is seen that the combination of the feedwater throttle (202), the evaporation zone throttle (201), and the turbine speed governor constitutes a mechanism which, for a given turbine load is responsive to the kinetic energy of the boiler fluid at the evaporation zone throttle in the normal position of the evaporation zone. It is the function of the mechanism to keep the kinetic energy of flow through this evaporation zone throttle nearly constant for any load, resulting in a motion which controls the opening of the feedwater throttle and the flow of feedwater into the boiler inlet in an appropriate manner.

With this system, the superheater operates under low pressure when the power plant is at light loads. Since the major portion of the throttling of the steam takes place at the evaporation zone, the steam entering the superheater is at a slightly lower temperature and at a higher velocity than if all the throttling were accomplished at the boiler outlet. This results in lower superheater tube temperature and a higher heat transfer rate in the superheater.

When it is desired to shut off the flow of boiler steam instantly the turbine nozzle control is brought to its seat, but at no time is the evaporation zone throttle completely closed. Therefore, when the turbine nozzle control is closed, there is an available pressure in the boiler superheater for instantaneous load demands.

In Figure 7 is shown a further modification of my control system for feedwater regulation.

The elements of the steam powerplant except as herein stated, remain as shown in Figure 1. A throttling valve (230) placed at the discharge of the feedwater pump is operated by an electrical mechanism (231) to control the flow of the feedwater. The feedwater progresses past a check valve (8) and a pressure responsive element (232) which is of the same construction as that shown and described in Figure 3, and finally enters the boiler inlet (10). At the evaporation zone (12) of the boiler a venturi (233) is placed, through which the boiler fluid must flow. A second pressure responsive device (234) is placed at the evaporation zone communicating with the Venturi throat (235) by means of a passage (236). Both pressure responsive devices have increased electrical conductivity when subjected to increased pressure.

The performance of this control depends upon the supply of current from a lead (237) being supplied to the electrical mechanism (231) and grounded through the pressure responsive devices (232) and (234) after passing through said mechanism. The greater the flow of current, the more the water flow is throttled off by the action of the feedwater throttling valve and the accompanying mechanism.

The pressure responsive device (232) at the inlet of the boiler is accordingly made more conductive and thereby tends to cause closure of the feedwater throttling valve when the boiler inlet pressure is high, due to the boiler pressure being high, or the feedwater flow being high. The pressure responsive element (234) communicating with the throat of the venturi through which the boiler fluid passes at the evaporation zone, is acted upon by high boiler pressure to reduce the feedwater supply to the bottom of the boiler. It is influenced by high velocity to increase the flow of feedwater to the boiler inlet due to the flow depression at the Venturi throat.

The pressure responsive device (234) at the evaporation zone is in reality a device responsive to the impounded pressure in the end of the economizer section and the kinetic energy imparted to the boiler fluid in entering the Venturi throat. With a given boiler pressure before the venturi, the greater the kinetic energy imparted to the boiler fluid at the throat, the lower will be the pressure acting upon the pressure responsive device located at the throat. Thus, when steam, which below critical pressures, is of greater volume than its corresponding liquid of saturation, flows through the Venturi throat, all other factors remaining the same, there will be a substantial reduction in pressure acting upon the pressure responsive device resulting in an increase of feedwater supply. When liquid enters the throat of the venturi, the Venturi throat depression will be relatively small, and the pressure acting upon the pressure responsive device will be about as high as that at the Venturi inlet or outlet.

The overall effect of the mechanism described in Figure 7 is to keep liquid up to but not beyond the venturi (233) at the evaporation zone, and to prevent the boiler pressure from becoming too high.

If the boiler is to be operated in the critical pressure range (over 220 atmospheres) such that the boiler contains dry saturated steam of the same approximate density as its corresponding saturated liquid, a depression during flow can be made to exist at the Venturi throat at a sub-critical pressure. The fluid pressure is subsequently reestablished in the mouth of the venturi to 220 atmospheres or over.

The flow of fluid of sub-critical pressure at the Venturi throat allows a differential kinetic energy measuring means to distinguish between liquid at the throat or steam at the throat, even though all the remaining portions of the boiler be at pressures above the critical.

If the operating pressure of the boiler is to be considerably more than the critical pressure, it is still possible to control the outlet temperature and pressure of the boiler for constancy, using this modified form of my boiler control system.

A duct (238) into the evaporation zone Venturi throat (235) is provided for injection of a liquid which removes deposits within the boiler tube. The boiler is fired dry, and cold water forced into the duct strikes the heated deposits

causing them to detach themselves from the boiler walls in the evaporation zone.

The duct (238) also serves as a means whereby water may be forced into an intermediate portion of the boiler to hasten the steaming up of the powerplant if the boiler is initially dry.

I claim:

1. A variable output boiler control comprising a long tube having an inlet adjacent one end, an outlet adjacent the other end, and an evaporation region between said ends, means for heating said tube, means for introducing feed liquid into said inlet, a restriction in said evaporation region regulated in size by the volumetric flow through said region, and means responsive to said volumetric flow of the boiler fluid in said restriction for controlling said introducing means.

2. A boiler control comprising a forced circulation boiler tube, means for heating said tube, means for forcing liquid to flow through said tube so that ebullition occurs at a region in said tube, a variable throttle in said region of ebullition, and means responsive to the rate of flow at said throttle for controlling said forcing means.

3. A variable output boiler control comprising a long heated tube, means for advancing feed liquid in said tube to evaporate in said tube, and variable volumetric metering means located in a predetermined portion of said tube to control the rate of advance of said feed liquid.

4. In combination, a long heated boiler tube, means for introducing feed liquid into an inlet end of said tube, means for discharging the superheated vapor of said liquid from the outlet end of said tube, a region of ebullition in said tube intermediate of said ends, a variable restriction responsive to kinetic energy of the fluid at said region of ebullition for controlling said feed liquid introducing means, and means responsive to flow of said liquid for modifying said control of liquid introducing means.

5. A boiler control comprising a long tube having an inlet adjacent one end, and an outlet adjacent the other end thereof, means for introducing liquid into said inlet, means for producing evaporation of said liquid in a predetermined region in said tube, means located at said region for imparting kinetic energy to the fluid in said region, means located at said region responsive to the rate of absorption of said energy in said fluid for controlling said introducing means.

6. A boiler control comprising a long heated tube, means for advancing feed liquid through said tube to become progressively heated and to evaporate in a predetermined portion of said tube and a variable throttling device located at the evaporation zone of said tube, said advancing means being controlled in relation to the boiler fluid pressure drop across said throttling device.

7. A boiler control comprising a long heated tube, means for advancing feed liquid through said tube to become progressively heated and to evaporate in a predetermined portion of said tube, a variable restriction directly responsive to fluid conditions at said portion and located in said portion, and means responsive to the degree of said restriction for controlling said advancing means.

8. In combination, a heated container having an inlet adjacent one end thereof, an outlet adjacent the other end thereof, means for supplying a feed liquid to said inlet to be progressively heated in said container and to be discharged from said outlet as a vapor at supercritical pressure, means intermediate of said ends for locally reducing the boiler fluid pressure below and subsequently restoring the boiler to said supercritical pressure and means responsive to the kinetic energy of the boiler fluid in said reduced locality for controlling said means for supplying feed liquid.

9. A mechanism for regulating boiler discharge comprising a long heated tube having an inlet adjacent one end thereof, an outlet adjacent the other end thereof, means for introducing feed liquid into said inlet to be progressively heated and to evaporate at a zone intermediate of said ends, a primary throttling means located at said outlet, and a main throttling means located at said zone and directly controlled by said primary throttling means.

10. A series tube steam generator control comprising a long heated tube having an inlet at one end, an outlet at the other end, an evaporation zone between said ends, means for supplying feed liquid to said inlet, means sensitive to the volumetric flow in said evaporation zone for controlling said supplying means, and means sensitive to compressibility of the fluid in said evaporation zone for modifying said control.

11. A boiler control for a continuous fluid flow system from inlet to outlet comprising an imperforate heated tube having an inlet at one end, an outlet at the other end, means for supplying feed liquid to said inlet, an evaporation zone between said ends, mechanical means located at said zone for varying the dynamic energy content of said boiler fluid at said zone, and means responsive to said energy content for controlling said feed liquid supplying means.

12. A boiler control comprising a long heated tube having an inlet at one end, an outlet at the other end, an evaporation zone intermediate of said ends, means for supplying feed liquid to said inlet, a venturi located in said evaporation zone, a movable member axially located in the throat of said venturi to be acted upon by flow through said throat, and means for regulating said feed liquid supplying means in accordance with the instantaneous position of said member.

13. The method of controlling a series tube steam generator operated from the feedwater inlet to the superheater discharge outlet at supercritical pressure, which utilizes the kinetic energy in the throat of a venturi so located in the generator that unbalance of the ratio of feedwater supply to steam formed results in a change of state of the fluid in said throat of said venturi at subcritical pressure, and regulating the feedwater supply from said unbalance.

14. In a vapor generator for variable output in combination, a long tube, means for supplying a liquid operating medium to the inlet of said tube at a supercritical pressure, means for superheating the vapor generated at a supercritical pressure by the external addition of heat, means sensitive to variation in kinetic energy for locally reducing the pressure of the generator fluid to a value below the critical and for controlling said liquid operating medium supplying means, said local reducing means located in the generator at a point where the evaporation zone would normally exist if the entire generator were operated at essentially the said pressure value below the critical.

15. A series tube generator control comprising a long heated tube having an inlet at one end

for feed liquid supply, and an outlet at the other end for the discharge of superheated vapor, an evaporation zone intermediate of said ends with variable cross-sectional area of said tube in said zone for controlling flow in said zone, and a regulation of said feed liquid supply and said superheated vapor discharge in accordance with the variation of said area.

16. A series tube generator control comprising a long heated tube having an inlet at one end for the supply of feed liquid thereto, an outlet at the other end for the discharge of superheated vapor therefrom, an evaporation zone intermediate of said ends, a first variable throttling device at said evaporation zone for controlling the flow through said zone, and a second throttling device rigidly connected to said first throttling device for regulating said feed liquid supply.

17. A series tube boiler control comprising a long heated liquid fed tube for the discharge of superheated vapor of said liquid, an evaporation zone in said tube and a variable throttling member in said tube for progressive and continuous regulation of the fluid flow from the inlet through the evaporation zone to the outlet of said tube.

18. A series tube boiler control comprising a liquid fed long imperforate tube for the discharge of superheated vapor of the entire quantity of said fed liquid at the outlet of said tube, an evaporation zone in said tube, means for extracting energy from the boiler fluid in said evaporation zone before it is admitted to the superheater, and a supply of said liquid to the inlet of said tube in accordance with said rate of extraction.

19. A series tube boiler control comprising a long heated liquid fed tube for the discharge of the superheated vapor of said liquid, an evaporation zone in said tube, variable means located at said zone for producing a force in counterflow direction to the fluid in said zone upon said fluid in accordance with the rate of feedwater supply.

20. The combination of a fuel combustion chamber for heating a container, an electrical resistance element variable in conductance by imposed pressure and temperature in said container, means for supplying a feed fluid to said container to be evaporated in said container, means for supplying electrical current to said element and to pass therethrough for controlling said feed fluid supplying means in accordance with the variation of conductance, and relationship through said variation such that the rate of supply of said feed fluid will be reduced by a relatively low dynamic pressure or by a relatively low temperature acting upon said element in said container and will be elevated by a relatively high dynamic pressure or by a relatively high temperature acting upon said element in said container.

21. The combination of a heated tube, means for forcing feed fluid into said tube to be discharged therefrom as a superheated vapor, an electrical resistance element varied in conductance by the fluid pressure at the evaporation zone in said tube, means for supplying electric current to said element, and means for controlling said forcing means in accordance with the variation in conductance and in accordance with the flow of said current effecting a control such that a greater amount of said feed fluid will be forced into said tube by an elevated dynamic pressure in said zone and such that a lesser amount of said feed fluid will be forced into said tube by a reduced dynamic pressure in said zone.

22. A boiler control comprising a heated forced circulation boiler tube fed with a liquid such that vaporization occurs at a region in said tube, a variable volumetric metering means in said region for controlling a supply instrumentality of said tube thereby to maintain a desired working condition in said tube, and said condition being related to the volumetric flow in said region.

NATHAN C. PRICE.