

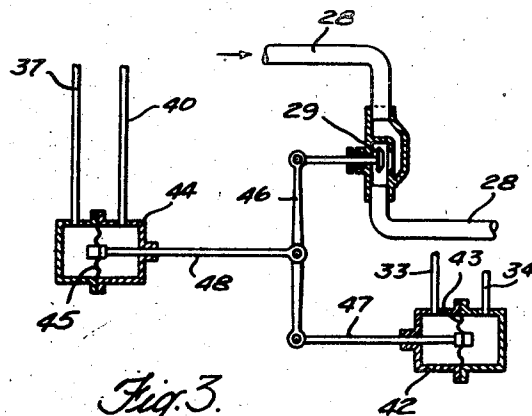
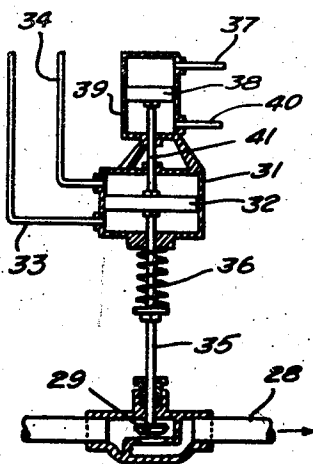
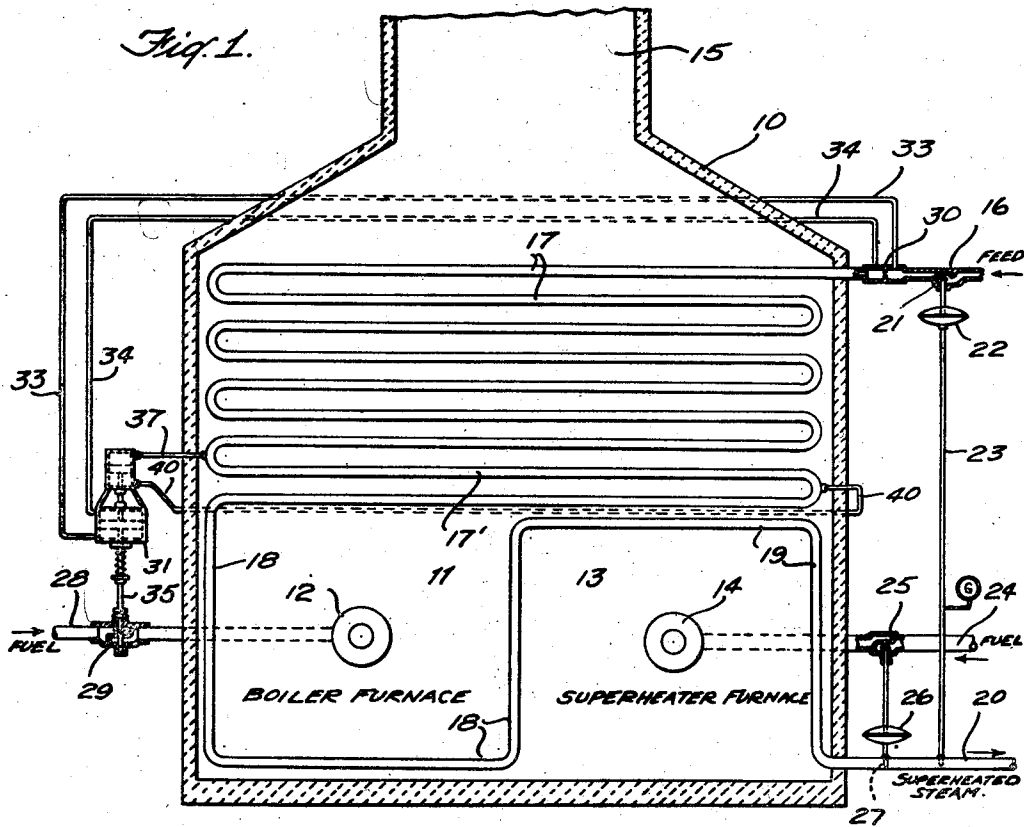
June 17, 1947.

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2,422,178

VAPOR GENERATOR

Filed March 19, 1942



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2,422,178

VAPOR GENERATOR

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Application March 19, 1942, Serial No. 435,258

14 Claims. (Cl. 122-448)

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This invention relates to the generation and the superheating of vapor, and more particularly pertains to controls therefor.

The invention provides automatic controls for a vapor generating and superheating system having separately fired vapor generating and superheating furnaces, which operates to maintain a predetermined final vapor temperature and pressure at all loads on the system, and upon a change in load on the system, to change momentarily the quantity of fuel delivered to the vapor generating furnace to a point beyond that which is required for the new load and in the same direction, and then gradually to change to the normal quantity required for the new load, thus reducing or eliminating the lag usually present in such control systems between the appearance of a new condition and the response to meet that condition.

The invention will be disclosed as applied to a steam generator of the once-through type, but it will be understood that it is capable of general application.

The invention will be understood from the following description considered in connection with the accompanying drawing forming a part thereof, and in which:

Fig. 1 is a more or less diagrammatic view in vertical section of a once-through steam boiler embodying the invention;

Fig. 2 is a vertical sectional view on an enlarged scale, of part of the differential control device shown in Fig. 1, and

Fig. 3 is a more or less diagrammatic sectional view of another form of differential control device which may be employed.

Like characters of reference refer to the same parts throughout the several views.

Referring to the drawing, reference character 10 designates the setting of a once-through boiler having a boiler furnace 11 fired by one or more fuel burners 12, and a separate superheater furnace 13 fired by one or more burners 14. The setting has a flue 15 in which may be located one or more heat recovery devices, such as an economizer or an air heater. Feed water is introduced into the boiler through feed line 16 and flows through the steam generating section having tubes 17 above both furnaces 11 and 13 and extensions 18 of these tubes disposed at three sides of the boiler furnace. Steam generated in the tubes 17 and 18 flows directly into the superheating section comprising extensions 19 of the tubes of the steam generating section, and which are disposed above and at one side of the superheater

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furnace 13. Superheated steam is discharged through steam line 20.

Feed line 16 has a valve 21 controlled by a diaphragm 22 which is actuated in response to changes in pressure of the superheated steam flowing from the boiler through discharge line 20, such pressure changes being transmitted through a line 23. If the pressure of the superheated steam in line 20 increases, feed valve 21 moves toward closed position and decreases the quantity of feed water delivered to the boiler, whereas if the pressure decreases, the feed valve is moved toward open position and increases the quantity of feed water delivered to the boiler.

Fuel is supplied to the burner 14 which fires the superheater furnace 13 through line 24 having a valve 25 which is controlled in response to the temperature of the superheated steam discharged by the boiler through line 20. Valve 25 is operated by a diaphragm 26 which is actuated in response to a thermostat 27 in line 20. If the temperature of the superheated steam falls below a predetermined point, valve 25 is moved toward open position and more fuel is delivered to the burner 14, whereas if the temperature rises above the predetermined point, the valve is moved toward closed position and less fuel is delivered to the burner.

Fuel is supplied to the burner 12 which fires the boiler furnace, through a line 28 having a valve 29 which is controlled in response to the differential pressures across two spaced resistances in the steam generating section of the boiler through which the water flows in series, the feed line 16 being considered part of the steam generating section. These resistances may be orifices or substantial portions of the evaporating surface of the steam generating section. As shown, the first resistance is an orifice 30 in the feed line 16, the opposite sides of which are connected with a control cylinder 31 at opposite sides of the piston 32 therein, line 33 connecting the inlet side of orifice 30 with the lower side of the piston 32, and line 34 connecting the outlet side of the orifice with the upper side of the piston, the arrangement being such that an increase in flow of feed water will move valve 29 toward open position and admit more fuel to the boiler furnace burner, and a decrease in the flow of feed water will move the valve toward closed position and admit less fuel to the burner. Valve 29 is connected to piston 32 through rod 35 upon which a coil spring 36 acts to urge the valve toward closed position. The second resistance constitutes a substantial portion 35 of the steam generating section, and as shown,

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is the length of tubing designated 17' at an intermediate portion of the steam generating section. The inlet end of this portion 17' is connected through line 37 with the upper side of a piston 38 in cylinder 39 disposed above cylinder 31, and the outlet end is connected through line 40 with the lower side of the piston. Piston 38 is connected to piston 32 through a rod 41. The arrangement is such that an increase in the flow through portion 17' will tend to move valve 29 toward closed position and a decrease in flow through this portion will tend to move valve 29 toward open position.

Flow through orifice 30 causes a pressure drop $P_1 - P_2$, where P_1 is the pressure on the inlet side of the orifice and P_2 is the pressure on the outlet side of the orifice. This pressure drop is substantially proportional to $w^2 S$, where w is the rate of flow of feed water to the boiler and S is the specific volume of the water. This flow of feed water exerts a force on the piston 32 of area A in cylinder 31 which is proportional to $(P_1 - P_2)A$ or $(w^2 S)A$, and which acts to move the valve toward open position upon an increase in flow of the feed water to the boiler. Similarly the resistance to flow through the portion 17' of the steam generating section exerts a force $(P_3 - P_4)a$ or $(w^2 s)a$ on the piston 38 of area " a " in the upper cylinder 39, which acts to move the valve 29 toward closed position upon an increase in the flow through portion 17', P_3 being the pressure at the inlet end of portion 17', P_4 being the pressure at the outlet end of portion 17', and " s " being the specific volume of the water and steam mixture flowing through portion 17'. The net opening of the valve 29 thus will be substantially proportional to $w^2(SA - sa)$.

When the boiler is operating steadily, valve 29 will be held open against the action of spring 36 by a force substantially proportional to $w^2(SA - sa)$. Should the load on the boiler increase, the pressure in line 20 will decrease which will cause feed water valve 16 to move to a more open position, thereby increasing the factor w and increasing the force tending to move valve 29 toward a more open position, in accordance with the formula, and increasing the flow of fuel to burner 12 in the boiler furnace. Initially, the specific volume s at a portion 17' of the steam generating section will decrease because of the lower pressure in the outlet line 20, but this specific volume will thereafter gradually increase as the pressure builds up in the outlet line 20. This will cause the force acting on valve 29, $w^2(SA - sa)$, to increase initially, and momentarily open the valve 29 more than is required for the new load, after which the force decreases gradually and moves the valve 29 to a more closed position until it attains its required position for that particular load on the boiler. Thus, the fuel supplied to the boiler furnace burner 12 is momentarily increased above the supply which is required for the new load and then is gradually reduced to the required amount. Contrariwise, should the load on the boiler decrease, the result will be the reverse of that just described, and the valve 29 momentarily will be closed more than would be necessary for the lower load, after which the valve would be opened gradually until it attained its correct position for the new load.

With this control system, it will be perceived that the time of response of the boiler to the controls is reduced materially, as compared with the lag which would be encountered if the quantity of fuel supplied to the boiler furnace burner were

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not changed momentarily to a greater extent than is required for the new load.

In the differential control device shown in Fig. 3, diaphragms instead of pistons are employed. Cylinder 42 having a diaphragm 43, the opposite sides of which are in communication with opposite sides of the orifice 30 in the feed line 16. Cylinder 44 has a diaphragm 45, the opposite sides of which are in communication with the ends of portion 17' of the steam generating section of the boiler. The stem of the valve 29 is pivotally connected to one end of a lever 46, the other end of which is pivotally connected to the rod 47 of diaphragm 43, and the central portion of which is pivotally connected to the rod 48 of the diaphragm 45. The mode of operation and the results obtained with this differential control device are substantially the same as described in connection with the corresponding device shown in Figs. 1 and 2.

Changes may be made in the form, location and relative arrangement of the several parts of the forms of the invention disclosed without departing from the principles of the invention. For example, an orifice may be employed in lieu of the portion 17' of the steam generating section, or a portion of the steam generating section 17 or a portion of the feed line 16, may be used instead of the orifice 30. Any suitable multiplying device or devices may be used with the differential control device, or the other control devices. Accordingly, the invention is not to be limited excepting by the scope of the appended claims.

What is claimed is:

1. A vapor generator comprising a vapor generating section, a superheating section, separate furnaces for said sections, means for independently firing each furnace, means responsive to a condition of the superheated vapor for controlling the means for firing the furnace for the superheating section, and means responsive to the differential pressure across spaced flow resistances in the path of fluid which flows through the vapor generating section for controlling the means for firing the furnace for the vapor generating section.

2. A vapor generator comprising a vapor generating section, a conduit through which feed liquid is delivered to said section, a superheating section, separate furnaces for said sections, means for independently firing each furnace, a valve in said conduit, means responsive to the pressure of the superheated vapor for controlling said valve, means responsive to the temperature of the superheated vapor for controlling the means for firing the furnace for the superheating section, and means responsive to the differential pressure across spaced flow resistances in the path of fluid which flows through the vapor generating section for controlling the means for firing the furnace for the vapor generating section.

3. A vapor generator comprising a vapor generating section, a conduit through which feed liquid is delivered to said section, a superheating section, separate furnaces for said sections, at least one burner for firing each furnace, a conduit through which fuel is delivered to the at least one burner for each furnace, a valve in each conduit, a valve in the feed liquid conduit, means responsive to the pressure of the superheated vapor for controlling the valve in the feed liquid conduit, means responsive to the temperature of the superheated vapor for controlling the valve in the conduit through which fuel is delivered to the at least one burner of the furnace for the

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superheating section, and means responsive to the differential pressure across spaced flow resistances in the path of fluid which flows through the vapor generating section for controlling the valve in the conduit through which fuel is delivered to the at least one burner of the furnace for the vapor generating section.

4. A vapor generator comprising a vapor generating section and a vapor superheating section connected to provide a continuous path of flow in which substantially all the liquid delivered to said path is vaporized, a furnace for the generating section, a furnace for the superheating section, a burner for firing each furnace, means for separately delivering fuel to each burner, means for controlling the supply of liquid to the generating section in response to the pressure of the vapor superheated in said superheating section, and means for controlling the supply of fuel to the burner for the generating section in response to the differential pressure across a plurality of flow resistances in the path of flow of the liquid vaporized and superheated in said path of flow.

5. The method of generating and superheating vapor which comprises flowing liquid in a path of flow wherein it is vaporized and the vapor is superheated, supplying fuel separately to separate combustion zones to produce separate streams of products of combustion, one of which flows in heat exchange relationship with the vaporizing part of said flow path and another of which flows in heat exchange relationship with the superheating part of said flow path, controlling the quantity of fuel delivered to the zone in which the first mentioned stream of products of combustion is produced in response to the differential pressure across a plurality of flow resistances in said path of flow, and controlling the quantity of fuel delivered to the zone in which the second-mentioned stream of products of combustion is produced in response to a condition of the superheated vapor.

6. The method of generating and superheating vapor which comprises flowing liquid in a path of flow wherein it is vaporized and the vapor is superheated, supplying fuel separately to separate combustion zones to produce separate streams of products of combustion one of which flows in heat exchange relationship with the vaporizing part of said flow path and another of which flows in heat exchange relationship with the superheating part of said flow path, controlling the quantity of fuel delivered to the zone in which the second mentioned stream of products of combustion is produced in response to the temperature of the vapor superheated in said flow path, and controlling the quantity of fuel delivered to the zone in which the first mentioned stream of products of combustion is produced in response to the differential pressure across a plurality of flow resistances in said path of flow.

7. The method of generating and superheating vapor which comprises flowing liquid in a path of flow wherein it is vaporized and the vapor is superheated, supplying fuel separately to separate combustion zones to produce separate streams of products of combustion one of which flows in heat exchange relationship with the vaporizing part of said flow path and another of which flows in heat exchange relationship with the superheating part of said flow path, controlling the quantity of fuel delivered to the zone in which the second mentioned stream of products of combustion is produced in response to the temperature of the vapor superheated in said

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flow path, and controlling the quantity of fuel delivered to the zone in which the first mentioned stream of products of combustion is produced in response to the differential pressure across a plurality of flow resistances in said path of flow, the operation being such that a change in flow of fluid through said flow path will cause said differential pressures to exert opposite effects upon the supply of fuel to the zone in which the first mentioned stream of products of combustion is produced.

8. A vapor generator comprising feed liquid delivery and vapor generating sections, means for delivering feed liquid to said sections, a furnace, means for firing the furnace, means for supplying fuel to the firing means, means for varying the amount of fuel supplied to said firing means, means for varying the quantity of feed liquid delivered to said sections in response to variations in load on the generator, means for controlling the furnace firing means comprising means responsive to differential pressure across a flow resistance in the path of fluid which flows through the feed delivery section, and other means for controlling the furnace firing means, said other means being responsive to differential pressure between spaced points within the vapor generating section, the arrangement being such that upon a change in load on the generator the quantity of fuel supplied to the firing means is changed momentarily to a greater extent than is necessary for the new load and then is returned to the required amount for the new load.

9. A vapor generator comprising feed liquid delivery and vapor generating sections, means for delivering feed liquid to said sections, a furnace, means for firing the furnace, means for supplying fuel to the firing means, means for varying the amount of fuel supplied to said firing means, means for varying the quantity of feed liquid delivered to said sections in response to variations in load on the generator, means for controlling the furnace firing means comprising means responsive to differential pressure across a flow resistance in the path of fluid which flows through the feed delivery section, and other means for controlling the furnace firing means, said other means being responsive to differential pressure between spaced points within the vapor generating section, the arrangement being such that the amount of fuel supplied to the firing means is changed to a greater extent than is required at a given load by a change in differential pressure across the flow resistance in said feed delivery section, and is returned to a normal amount for said given load by a change in differential pressure across the spaced points within the vapor generating section.

10. A vapor generator comprising feed liquid delivery and vapor generating sections connected to provide a continuous path of flow in which substantially all the liquid delivered to said path is vaporized, means for delivering feed liquid to said sections, means for varying the amount of feed liquid delivered in said sections in response to variations in load on the generator, a furnace, a burner for firing the furnace, a conduit through which fuel is delivered to the burner, a valve in said conduit, a plurality of pressure responsive devices connected to said valve, pressure transmitting means connecting opposite sides of one of said pressure responsive devices with opposite sides of a flow resistance in the path of fluid which flows through the feed delivery sections of the generator, and other pressure transmitting

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means connecting opposite sides of another of said pressure responsive devices with spaced points within the vapor generating section of the generator, the arrangement being such that the amount of fuel supplied to the burner is changed to a greater extent than is required at a given load by change in differential pressure across the flow resistance in the feed delivery section, and is returned to a normal amount for said given load by a change in differential pressure between the spaced points within the vapor generating section.

11. A vapor generator comprising feed liquid delivery and vapor generating sections connected to provide a continuous path of flow in which substantially all the liquid delivered to said path is vaporized, means for delivering feed liquid to said sections, means for varying the amount of feed liquid delivered in said sections in response to variations in load on the generator, a furnace, a burner for firing the furnace, a conduit through which fuel is delivered to the burner, a valve in said conduit, a plurality of pressure responsive devices connected to said valve, pressure transmitting means connecting opposite sides of one of said pressure responsive devices with opposite sides of a flow resistance in the path of fluid which flows through the feed delivery section of the generator, and other pressure transmitting means connecting opposite sides of another of said pressure responsive devices with spaced points within the vapor generating section of the generator, said pressure transmitting means being connected to said pressure responsive devices in such manner that a change in flow of fluid through said path of flow will cause said pressure responsive devices to have opposite effects on the movement of said valve, the arrangement being such that the amount of fuel supplied to the burner is changed to a greater extent than is required at a given load by change in differential pressure across the flow resistance in the feed delivery section, and is returned to a normal amount for said given load by a change in differential pressure between the spaced points within the vapor generating section.

12. A vapor generator comprising feed liquid delivery and vapor generating sections connected to provide a continuous path of flow in which substantially all the liquid delivered to said path is vaporized, means for delivering feed liquid to said sections, means for varying the amount of feed liquid delivered in said sections in response to variations in load on the generator, a furnace, a burner for firing the furnace, a conduit through which fuel is delivered to the burner, a valve in said conduit, a plurality of pistons each movable in a separate cylinder and connected to said valve, tubular members connecting opposite sides of a flow resistance in the path of fluid which flows through the feed delivery section of the generator with one of said cylinders at opposite sides of the piston therein, and other tubular members connecting spaced points within the vapor generating section of the generator with another of said cylinders at opposite sides of the piston therein, said tubular members being connected to said cylinders in such manner that a change in flow of fluid through said path of flow will cause said pistons to exert forces in opposite directions on said valve, the arrangement being such that the amount of fuel supplied to the burner is changed to a greater extent than is

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required at a given load by change in differential pressure across the flow resistance in the feed delivery section, and is returned to a normal amount for said given load by a change in differential pressure between the spaced points within the vapor generating section.

13. A vapor generator comprising feed liquid delivery and vapor generating sections connected to provide a continuous path of flow in which substantially all the liquid delivered to said path is vaporized, means for delivering feed liquid to said sections, means for varying the amount of feed liquid delivered in said sections in response to variations in load on the generator, a furnace, a burner for firing the furnace, a conduit through which fuel is delivered to the burner, a valve in said conduit, a plurality of diaphragms connected to said valve, tubular members connecting opposite sides of a flow resistance in the path of fluid which flows through the feed delivery section of the generator with opposite sides of one diaphragm, and other tubular members connecting spaced points within the path of flow of fluid which flows through the vapor generating section of the generator with opposite sides of another diaphragm, said tubular members being connected to said diaphragms in such manner that a change in flow of fluid through said path of flow will cause said diaphragms to exert forces in opposite directions on said valve, the arrangement being such that the amount of fuel supplied to the burner is changed to a greater extent than is required at a given load by change in differential pressure across the flow resistance in the feed delivery section, and is returned to a normal amount for said given load by a change in differential pressure between the spaced points within the vapor generating section.

14. The method of generating vapor which comprises flowing liquid in a path of flow comprising a feed liquid delivery zone and a vapor generating zone; burning fuel to supply heat to said flow path to generate vapor, varying the liquid fed to said flow path in response to variations in load on the generator, changing the quantity of fuel burned upon a change in load on the generator to a greater extent than is necessary at a given load in response to change in the differential pressure across a flow resistance in the feed liquid delivery zone, and returning the quantity of fuel burned to the required amount for said given load in response to change in the differential pressure between the spaced points within the vapor generating zone.

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