Sept. 30, 1952 H. C. MITTENDORF ET AL 2,612,593

CONTROL SYSTEM FOR ELECTRIC STEAM GENERATORS

Filed July 25, 1947 4 Sheets-Sheet 1

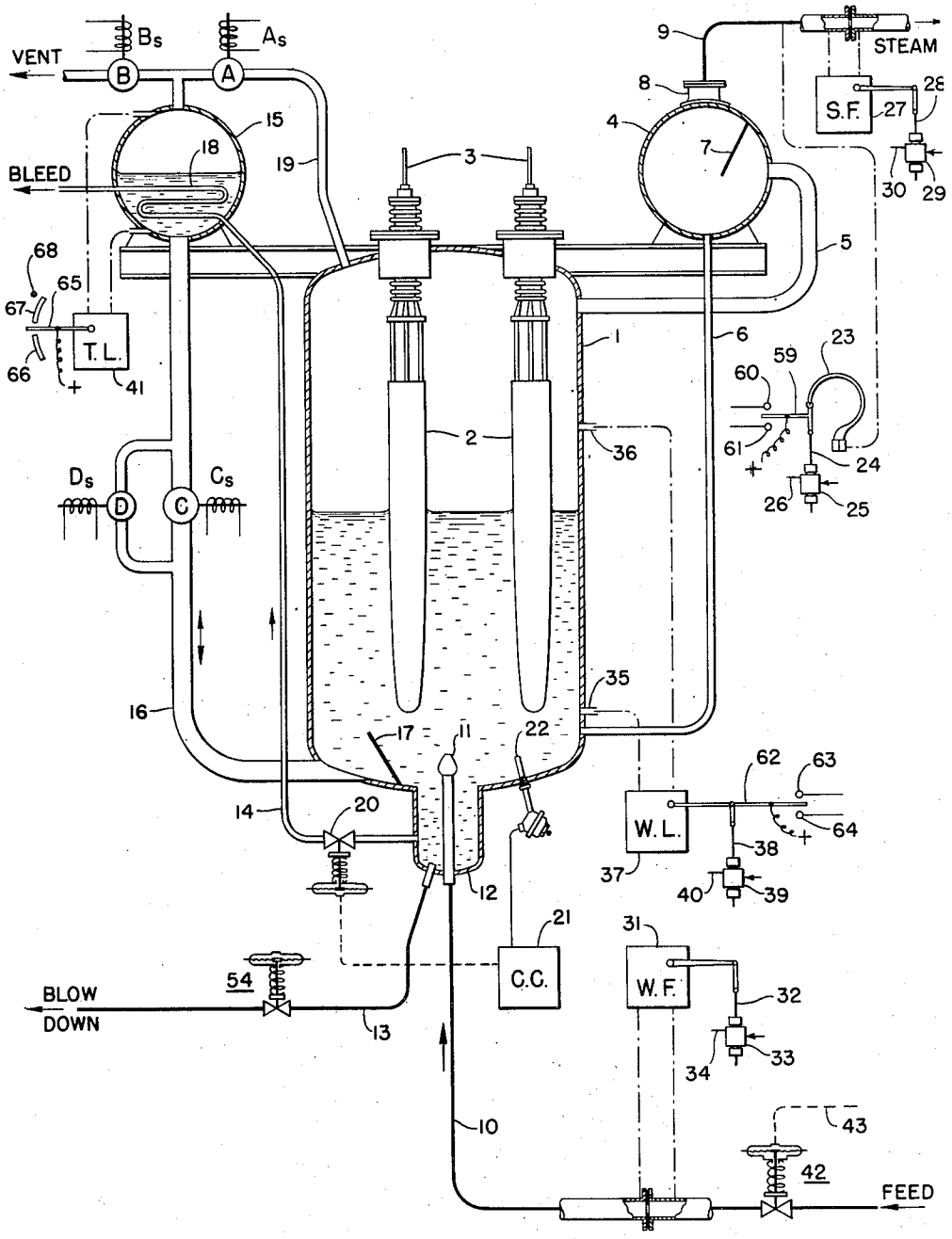


FIG. 1

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CONTROL SYSTEM FOR ELECTRIC STEAM GENERATORS

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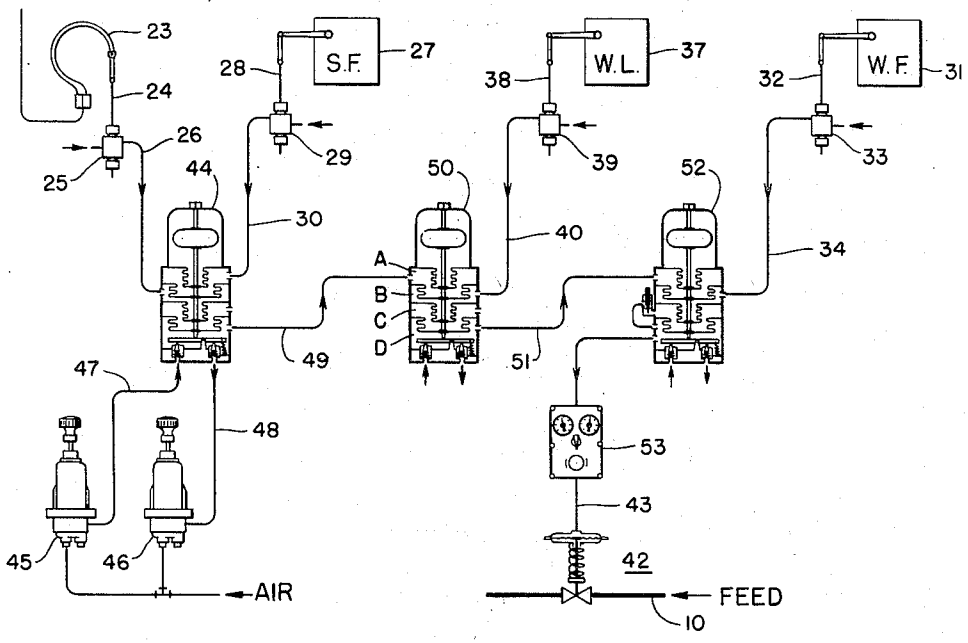


FIG. 2

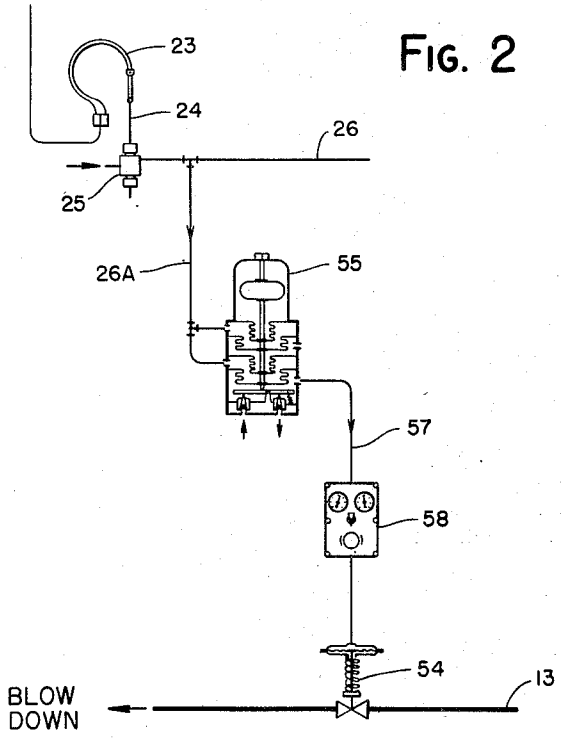


FIG. 3

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CONTROL SYSTEM FOR ELECTRIC STEAM GENERATORS

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BOILER ELECTRODE IMMERSION	STEAM PRESSURE	TANK WATER LEVEL	OPERATING CONDITION	DIRECTION OF WATER TRANSFER	RATE OF WATER TRANSFER	VALVE POSITION * A	B	C	D
MAXIMUM IMMERSION LIMIT	HIGH	FULL	1	NONE	NONE	O	C	C	C
		HIGH	2	TO TANK	FAST	C	O	O	O
		MID± 2"	3	TO TANK	FAST	C	O	O	O
		LOW	4	TO TANK	FAST	C	O	O	O
	NORMAL	FULL	5	NONE	NONE	O	C	C	C
		HIGH	6	NONE	NONE	O	C	C	C
		MID± 2"	7	NONE	NONE	O	C	C	C
		LOW	8	TO TANK	SLOW	C	O	C	O
	LOW	FULL	9	NONE	NONE	O	C	C	C
		HIGH	10	NONE	NONE	O	C	C	C
		MID± 2"	11	NONE	NONE	O	C	C	C
		LOW	12	NONE	NONE	O	C	C	C
OPERATING RANGE	HIGH	FULL	13	NONE	NONE	O	C	C	C
		HIGH	14	TO TANK	FAST	C	O	O	O
		MID± 2"	15	TO TANK	FAST	C	O	O	O
		LOW	16	TO TANK	FAST	C	O	O	O
	NORMAL	FULL	17	TO BOILER	SLOW	O	C	C	O
		HIGH	18	TO BOILER	SLOW	O	C	C	O
		MID± 2"	19	NONE	NONE	O	C	C	C
		LOW	20	TO TANK	SLOW	C	O	C	O
	LOW	FULL	21	TO BOILER	FAST	O	C	O	O
		HIGH	22	TO BOILER	FAST	O	C	O	O
		MID± 2"	23	TO BOILER	FAST	O	C	O	O
		LOW	24	TO BOILER	FAST	O	C	O	O
MINIMUM IMMERSION LIMIT	HIGH	FULL	25	NONE	NONE	O	C	C	C
		HIGH	26	NONE	NONE	O	C	C	C
		MID± 2"	27	NONE	NONE	O	C	C	C
		LOW	28	NONE	NONE	O	C	C	C
	NORMAL	FULL	29	TO BOILER	SLOW	O	C	C	O
		HIGH	30	TO BOILER	SLOW	O	C	C	O
		MID± 2"	31	NONE	NONE	O	C	C	C
		LOW	32	NONE	NONE	O	C	C	C
	LOW	FULL	33	TO BOILER	FAST	O	C	O	O
		HIGH	34	TO BOILER	FAST	O	C	O	O
		MID ± 2"	35	TO BOILER	FAST	O	C	O	O
		LOW	36	TO BOILER	FAST	O	C	O	O

* C=CLOSED ; O=OPEN

FIG. 4

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CONTROL SYSTEM FOR ELECTRIC STEAM GENERATORS

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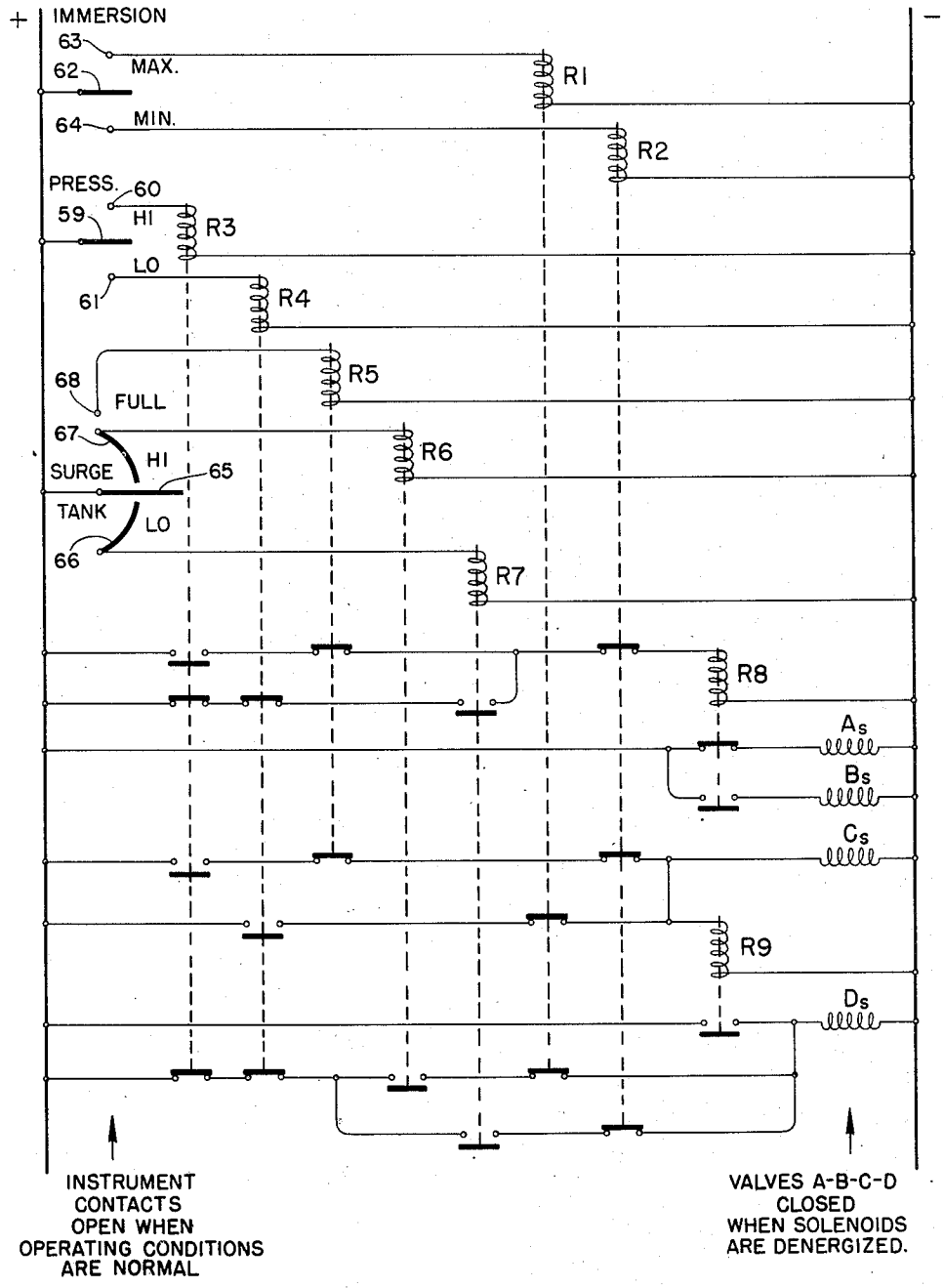


FIG. 5

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Patented Sept. 30, 1952 2,612,593

UNITED STATES PATENT OFFICE

2,612,593

CONTROL SYSTEM FOR ELECTRIC STEAM GENERATORS

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Application July 25, 1947, Serial No. 763,700

34 Claims. (Cl. 219—40)

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This invention relates to control systems and particularly to method and apparatus adapted to control the operation of a power producing apparatus such as an electrically heated vapor generator.

In certain localities where hydro-power is abundant, the price of electricity is low enough to make economical its use in vaporizing water into steam for process or other purposes. In the operation of such vapor generators problems of control arise which must be solved in order that the temperature and pressure of the produced steam will be of uniform optimum value under existing demand conditions and with full safety to life and apparatus.

It is an object of our invention to provide both method and apparatus of control for an electrically heated vapor generator.

We have as a further object the provision of a completely automatic control system for such a vapor generator.

Other objects will become evident upon a study of the specification, drawings and claims.

In the drawings:

Fig. 1 is a diagrammatic representation of one preferred embodiment of our invention applied to an electrically heated steam generator.

Fig. 2 diagrammatically illustrates a pneumatic control system for regulating the rate of supply of feed water to the boiler of Fig. 1.

Fig. 3 diagrammatically illustrates a pneumatic control for regulating the blow-down from the boiler of Fig. 1.

Fig. 4 is a chart of conditions in the operation of the unit of Fig. 1.

Fig. 5 is an across-the-line diagram of electrical circuits for actuating certain valves of Fig. 1 to accomplish the sequential operation charted in Fig. 4.

Referring to the drawings, the particular unit being described and to which our control is applied, includes a vertically mounted drum or pressure vessel 1 supported in customary manner (not shown). Insulated through the upper head of the drum 1 and suspended therefrom are three equally spaced electrodes 2 (two only being shown in Fig. 1), which may be of cast iron or other suitable material. The three electrodes are usually enclosed by a clover leaf neutral plate properly spaced from the electrodes and from the inner surface of the drum wall. The terminals 3 of the electrodes are connected through

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the necessary electrical apparatus to a source of electrical power (usually 3-phase); the arrangement forming no part of the present invention.

External to and above the drum 1 is a horizontally supported dry drum 4 having a plurality of steam riser tubes 5 and one or more dry drum drain tubes 6. Known baffle arrangements 7 are incorporated within the dry drum 4 to separate from the steam any water which may be carried over or condensed. The boiler drum 1 is provided with the usual water column and gage glasses (not shown), while the dry drum 4 is provided with the usual safety valve (not shown) and with a main steam exit nozzle 8 discharging to a steam header 9. Water is supplied to the unit through a feed pipe 10 terminating in a feed nozzle 11 centrally located in the lowermost portion of the main drum 1. To a settling chamber portion 12 at the base of the drum 1 is also connected a blowdown line 13 and a bleed line 14.

The problems with which our method and apparatus are concerned is the supply of water to the unit, the extraction of water therefrom, the maintenance of desired level of liquid within the drum 1, as well as the conductivity of the liquid within the drum; all in proper degree so that the vapor which is generated will satisfy the rate demand while maintaining the desired pressure.

In such a vapor generator, the heat for vaporizing the water is supplied by the passage of electric current through the water itself, from one electrode to another, or to the neutral plate. Since the voltage of the power supply is constant, the energy consumed varies directly with the current, while the current varies inversely as the resistance of the path it travels. The resistance of the path, in turn, depends upon the cross-sectional area of the water conductor (path) and upon the specific resistance of the water itself. Inasmuch as the electrodes are fixed in position, the water area through which the current can pass is determined by the depth of immersion of the electrodes; i. e. the height of water within the boiler drum. The specific resistance of the water is a function of the concentration or amount of dissolved solids in the water and also the temperature of the water.

Thus, in a boiler of this type, the amount of steam generated depends upon the amount of electric current passing through the water and

this, in turn, depends upon the area of the path through the water and upon the conductivity (or resistivity) of the water to the passage of electric current therethrough. The water area through which the current can pass is determined by the depth of immersion of the electrodes. Therefore, if we maintain a constant specific resistance of the water, the amount of steam generated may be controlled by varying the level of the water in the boiler.

Thus, in order to maintain a substantially uniform value of steam pressure, while satisfying the demand upon the boiler for quantity rate of steam generated, we are confronted with the problem of controlling the level of liquid within the boiler drum as well as the specific resistance of the water. A variation in any one, or all, of the three variables, namely, the amount of water within the boiler, its concentration of impurities, or its temperature, may cause a desirable or an undesirable variation in steam pressure and/or rate of steam generation.

The water fed to the unit will always contain a certain percentage of dissolved or suspended solids, and particularly if the greater portion of water supplied is other than condensate. Inasmuch as the steam does not carry away any appreciable amount of salts or solids from the boiler, there is a continuous tendency to build up the concentration of solids within the boiler water, and thus to continually decrease the resistivity to current passage through the water path. When operating at rated capacity the boiler may hourly evaporate many times the water normally contained in it. In general, it may be said that if the conductivity of the water is maintained substantially uniform the rate of steam generation will vary with the water level or extent of immersion of the electrodes in the water pool. Conversely, if the level is maintained substantially uniform, then the rate of steam generation will vary with the concentration of dissolved salts in the boiler water. In order to keep the concentration of the water from gradually increasing (which would make inaccurate any functional relationship between water level and vapor generation) it is advisable to continually bleed some part of the highly concentrated water from the lower portion of the boiler drum in a controlled manner. If this is properly accomplished then a control of level within the drum is a control of rate of steam generation.

The interrelation of the effects of the operating variables may, however, cause disturbances in the primary control of level or of conductivity. For example, the conductivity of the water is not only a function of the amount of dissolved solids therein, but is also a function of the temperature of the water (increasing with temperature).

By way of example; if there is an increase in demand upon the vapor generator the steam pressure will tend to fall. Assuming for the moment a uniform conductivity of the water, then the increase in demand indicates a desirability of raising the level of water within the boiler, and thus increasing the path for electric current, thereby increasing the rate of current dissipation and consequently the rate of steam generation. However, a rapid increase in the rate of supply of water will tend to dilute the water within the boiler, thus lowering its conductivity, and at the same time will tend to cool the water within the boiler, which also effects a lowering of its conductivity. Both of these adverse effects are opposite in nature to a desired increase in vapor generation as would be expected through increasing the level and thus the area of conductor path. It is, therefore, apparent that a proper control must be judicious in regard to varying the level of water and must definitely take into account such adverse effects as have been mentioned.

It is known to provide a generating unit of this type with a storage or surge tank to which water may be transferred from the boiler, or from which water may be fed to the boiler. Such a surge tank **15** is shown in Fig. 1 as being of substantially the same size as the dry drum **4** and supported above the boiler **1** in a similar manner. Preferably the surge tank **15** is a cylindrical pressure vessel, supported horizontally, to minimize changes in static head due to level changes when water is transferred to or from the tank. The horizontal length of the tank is chosen in accordance with the water storage capacity desired, in relation to the size of the boiler **1**, its steaming capacity, and the extent and rapidity of demand fluctuations expected. Certain features of the surge tank **15** and of the heat exchanger **18** are disclosed and claimed in Patent No. 2,485,762 to Harvey C. Mittendorf.

Water within the tank **15** is transferred thereto from the boiler **1**, through a pipe **16**, the pipe **16** communicating with the boiler **1** at a location such that the water transferred to the tank **15** is of a temperature and conductivity fairly representative of the water in the pool in which the electrodes are immersed, i. e. shielded by a baffle **17** from the relatively colder and lower concentration feed water being admitted through the nozzle **11** and not from the settling chamber section **12**.

While the water stored in the tank **15** is at substantially the same pressure and temperature as the water in the boiler proper, there is of course some heat loss due to radiation. In order to conserve the heat of the highly concentrated bleed water controllably discharged through the pipe **14**, and to maintain the water within the tank **15** at or near boiler water temperature as possible, we pass the bleed through a heat exchange coil **18** located in the tank **15**.

Water is transferred between the boiler **1** and the surge tank **15** through the pipe **16** under the control of a relatively large solenoid actuated valve C and a relatively small solenoid actuated valve D, the latter by-passing the valve C.

The top of the tank **15** is placed in communication with the top of boiler **1** through a pipe **19** under the control of a solenoid actuated valve A and the tank may be vented to the atmosphere or to a lower pressure area through a solenoid actuated valve B. In order to avoid complicating Fig. 1 we have chosen to show the various electrical circuits in Fig. 5, while in Fig. 4 we have tabulated the "open" or "closed" positions of valves A—B—C—D for various operating conditions.

In the operation of an electrically heated vapor generator, and particularly one which is subjected to relatively rapid and wide load demands, a study of the relation between concentration of salts or solids in the water and the electrical current dissipation has shown that concentration has a very important bearing on the performance of the unit. The purpose of the surge tank is primarily to assist in holding the concentration of the boiler water uniform during load changes,

against the adverse effect of dilution of the boiler pool by feed water of low concentration and temperature. For the surge tank to be useful in handling load swings its water and heat storage must be of sufficient magnitude to nearly satisfy the load swing vaporization.

The continual evaporation of water in the drum 1 tends to increase the concentration of the salts and impurities in the water pool in which the electrodes are immersed. In order that steaming rate may be primarily controlled by the amount of electrode immersion, it is essential that the concentration value of the pool be maintained as nearly uniform as possible. The transfer of water to (on decreasing steam demands) and from (on increasing steam demands) the surge tank serves to minimize the concentration dilution and temperature quenching effect of sudden drastic increases in rate of fresh water infeed. We provide additionally a check back from a measure of concentration or conductivity of the pool water, by regulating a bleed of highly concentrated water from a measure of conductivity.

In Fig. 1 we have shown the bleed pipe 14 connected to the settling chamber 12. Located in the pipe 14 is a regulating valve 20 under the control of a conductivity controller 21 responsive to a conductivity cell 22, which is sensitive to the conductivity of the pool water at a selected location in the drum 1. We have found that, particularly on rapidly and widely swinging steam demands, the conductivity control of bleed is not alone sufficient, due to instrument time lag and also because it is not practical to sample from the conducting path directly from the active area between the electrodes themselves. Under such operating conditions we preferably employ both a controlled bleed of highly concentrated water and the automatic transfer of water between the boiler and the surge tank as described.

The primary functions of our control system may be summarized as follows:

1. To so control the rate of admission of feed water to the unit as to maintain a uniform steam pressure, through varying the liquid immersion of the electrodes in relation to steam demand. We preferably control the rate of admission of feed water conjointly from steam pressure, steam flow rate, water flow rate, and water level within the boiler; with the demand factors (steam pressure and steam flow rate) so limited in their dictates as to prevent exceeding the desired high and low immersion of the electrodes.

2. To controllably bleed highly concentrated water from the unit under the dictates of a conductivity sensitive device and to transfer water between the pool and a storage tank under changing load demands, all for the purpose of maintaining the conductivity of the water in which the electrodes are immersed substantially constant at all levels and rates of operation, to the end that a control of extent of immersion becomes a control of vaporization.

3. To prevent abnormal high water level in the boiler by an emergency blowdown.

Giving consideration to such disturbing influences as have been mentioned, which are effective principally under conditions of wide and rapid variations in demand, the arrangement of Fig. 1 is particularly directed to most efficient operation of a unit subjected to varying load demands, although not limited thereto.

Theoretically, with a constant voltage applied to the electrodes, and a uniform conductivity of the boiler water, the rate of steam generation will vary directly with the extent of immersion of the electrodes, i. e. the level of water in the boiler. Thus we desire a geared range between steam pressure (as an indication of demand upon the boiler) and water level, namely, a definite relation between level and load demand.

Connected to the steam outflow conduit 9 we show a Bourdon tube 23 sensitive to pressure of the steam and arranged to vertically position the stem 24, of a pneumatic pilot valve 25, which is adapted to establish in the pipe 26 an air loading pressure bearing a definite relation to the pressure of the steam in the conduit 9. Such a pilot valve is described in the patent to Johnson 2,054,464. We further provide a measuring device 27 arranged to vertically position the stem 28, of a pilot valve 29, to establish in the pipe 30 an air loading pressure continuously representative of the weight rate of flow of steam leaving the dry drum 4 through the conduit 9.

In connection with the feed water supply conduit 10 we show a water flow measuring device 31 arranged to vertically position the stem 32, of a pneumatic pilot valve 33, thereby continually establishing in the pipe 34 an air loading pressure directly representative of weight rate of flow of feed water through the pipe 10 to the boiler 1.

Spanning the vertical elevation of the boiler 1, at predetermined maximum and minimum water level limits, are pipe connections 35—36, connected to a water level measuring device 37, arranged to vertically position the stem 38, of a pneumatic pilot valve 39, continuously establishing in the pipe 40 an air loading pressure representative of the level of liquid within the drum 1 between the points of connection of pipes 35—36, and thus continually representative of the liquid immersion of the electrodes 2. In similar fashion we indicate at 41 a level measuring device spanning the elevation of the tank 15.

Referring now to Fig. 2, it will be seen that the rate of supply of water to the drum 1, through the pipe 10, is controlled by a valve 42 which is positioned under the dictates of four variables in the operation of the unit. It is apparent that under any steady load condition the rate of liquid inflow to the boiler should equal the weight rate of vapor outflow plus the bleed. Therefor the primary demand or load factor will be from steam outflow. This primary control factor may then be readjusted from steam pressure so as to quickly anticipate load changes. As steam pressure decreases (indicating increased demand or steam outflow) the rate of water supplied to the boiler will be increased proportionately to the deviation of steam pressure from standard. The electrodes are subject to wearing away or scaling up, with consequent variation in steam generation rate per inch of submergence. Steam pressure as an element in the control of feed water supply has the advantage of correcting for such changes in the relationship between level and rate of steam output.

Should there be fluctuations in feed water pressure, the feed water flow will fluctuate accordingly, so that a measure of water level is used to modify the primary demand effect so as to maintain the level at a proper value. This control so far described tends to maintain a definite water level for a given load demand.

There will, however, be little effect upon the valve 42 from the steam pressure controller or from the water level controller inasmuch as under such steady load condition these variables

should not be fluctuating. However, should any of the variables tend to fluctuate they will impose a correction upon the loading pressure within the pipe **43** leading to the valve **42** and correspondingly correct the rate of water input to the boiler.

As a final check-back we use a measure of actual weight rate of water flow through the pipe **10**, to the boiler, as a fourth element effective in positioning the control valve **42**.

The steam flow controller and the water flow controller are each designed on a weight rate basis for proper comparison. Should there be a deviation in steam pressure, steam temperature or feed water pressure one or the other of these flow controllers may give a slightly incorrect representation of the true weight rate. Thus a direct comparison between the two might indicate a proper proportionality between weight rate of liquid inflow and weight rate of vapor outflow, whereas actually the proportion would not be exactly correct. With the check back, however, from actual water level such discrepancy will be corrected. At the same time the modified control from steam pressure will be effective to take care of minor departures in steam pressure from the desired value.

When a change in load (for example an increase in steam demand) occurs, this will show up as an increase in the steam flow and a corresponding decrease in steam pressure. As previously mentioned, the desired operation is to raise the water level on the electrodes to increase the rate of steam generation. The increased steam flow and the decreased steam pressure will act in the same direction to demand an increase in rate of feed water until the comparison between steam outflow rate and feed water input rate attains desired proportionality. If the water level has not reached the proper value to satisfy the new demand, the water level controller will impose its control upon the feed water valve **42**. In general, the four variables, namely, steam outflow, water inflow, steam pressure and water level, will coact to properly position the feed input valve **42** to satisfy the steam demand upon the unit and maintain steam pressure substantially uniform.

It will be appreciated that the various control instrumentalities, such as regulators, relays, pilot valves, etc., may be adjusted for sensitivity, range, limits, etc. Inasmuch as such adjustments are known, it does not appear to be necessary to go into the details thereof.

It may be said that in Fig. 2 an air loading pressure is established within the pipe **26** representative of steam pressure, an air loading pressure within the pipe **30** representative of weight rate of steam outflow, an air loading pressure within the pipe **40** representative of water level within the boiler drum **1**, while an air loading pressure is established in the pipe **34** representative of weight rate of water feeding the boiler.

We apply the steam flow effect to the A chamber of a relay **44**, to the B chamber of which we apply the steam pressure effect. Connected to the inlet and outlet valves of the relay **44** are load limiting relays **45**, **46** supplied with air under pressure from a source (not shown). The relays **45**, **46** supply air at selected reduced pressures to the pipes **47**, **48** respectively, joining the D chamber of relay **44**. By way of example, the pressure in the pipe **47** may be limited to 25 p. s. i., while the pressure in the pipe **48** may be limited to 5 p. s. i.

Variations in the loading pressures, effective in the chambers A and B, produce a control pressure in the chamber D to which is connected the pipe **49**. The C chamber is open to the atmosphere. The result is that for any change in the loading pressures applied to the A chamber or to the B chamber the control pressure in chamber D will vary proportionately and in proper direction.

We desirably limit the water level in the boiler drum to a maximum and a minimum value irrespective of steam pressure conditions. When the loading pressure from the relay **44** (in pipe **49**) reaches either a minimum or a maximum value, as determined by the adjustment of the limiting relays **45**, **46**, no further change in loading pressure from the relay **44** can be applied to the relay **50**. Under such conditions the water level controller **37**, connected to the B chamber of relay **50**, assumes precedence over the demand effect of steam pressure and steam flow, and maintains the water level in the boiler drum within the desired limits without regard to steam pressure or steam flow changes. Thus the boiler is prevented from flooding or from becoming empty.

The limiting relays **45**, **46** are each provided with an adjustable orifice bleeding to the atmosphere so as to definitely establish the maximum pressure which may be experienced in the lines **47**, **48** respectively. In order to limit the maximum and minimum values of the control pressure available in the pipe **49** we limit the maximum air pressure in the pipes **47**, **48** and thereby in the D chamber of relay **44**. Assuming that a maximum pressure of 25 p. s. i. is available in the pipe **47**, through adjustment of the bleed valve of the relay **45** and therefor to the inlet of the chamber D, then this is the maximum control pressure which can be applied to the pipe **49** when the inlet valve is open and the outlet valve of the relay **44** is closed. Under a reversed condition, when the inlet valve of relay **44** is closed and the outlet valve is open, the bleed valve of limiting relay **46** is so adjusted that the pressures within the chamber D of relay **44** cannot decrease below a minimum of say 5 p. s. i.

The loading pressure resultant from steam pressure and steam flow, available in the pipe **49**, is applied to the A chamber of a relay **50** for comparison with the water level effect which is available within the B chamber from the pipe **40**. The output of the relay **50**, available through a pipe **51**, is applied to the A chamber of a standardizing relay **52**, to the B chamber of which we apply the water flow effect through the pipe **34**.

The output of the relay **52** is available in the pipe **43** for positioning the feed valve **42**. Interposed in the pipe **43** we provide a selector valve **53** similar to the type described in the patent to Fitch 2,202,485, thus providing a possibility for remote manual or automatic selective control of the valve **42**.

The relay **52** is of a standardizing type described in the patent to Gorrie, 2,098,914. Variations in pressure within the A chamber or the B chamber of the relay initially vary the control pressure within the pipe **43** with a standardizing follow-up variation in such control pressure accomplished through the agency of the adjustable bleed between the D and C chambers of the relay as fully described in said Gorrie patent.

It will be evident from a study of Fig. 2 that the differential relay **44** continually interrelates pressures individually representative of the two operation variables first to show the effect of

changes in demand upon the boiler, namely, steam pressure and steam outflow rate. Either or both of these operation variables may change, but normally they vary in opposite direction, i. e. an increase in steam outflow rate is accompanied by a decrease in steam pressure, and vice versa. Thus, upon an increase in steam outflow, the pressure within the A chamber of relay **44** will increase, while the pressure within the B chamber will decrease. These effects are additive to increase the loading pressure output of the relay **44**, through the pipe **49** to the A chamber of relay **50**, resulting in an increase in pressure within the chamber A of relay **52** and in an opening of the feed valve **42**.

The resultant effect of steam flow and steam pressure (in chamber A of relay **50**) is modified in accordance with water level as imposed upon the B chamber. Likewise, the pressure effect in the A chamber of relay **52** is modified by a pressure in the B chamber representative of water flow rate. Thus when the valve **42** is positioned to satisfy the dictates of steam pressure, steam flow and water level, it should result in a rate of feed water admission to the boiler such as to satisfy said three variables. As a check upon the actual rate of water flow, the water flow meter **31** establishes a loading pressure representative of water flow rate within the B chamber of relay **52**, and compares this against the effect established within the chamber A. If the proper rate of water admission is not attained, due perhaps to fluctuations in feed water pressure, then the positioning of the valve **42** is modified responsive to the interrelation between the pressure effects within the chambers A and B of relay **52**.

In addition to the high and low water level limits described in connection with the relay **44**, we provide an emergency blowdown system including a blowdown valve **54** interposed in the blowdown pipe **13** and under the control of steam pressure through the agency of a relay **55**.

The relay **55** assists the steam pressure controller in maintaining steam pressure within desired limits upon a suddden decrease in steam demand. Normally, the blow down valve **54** is closed. Should a sudden decrease in steam outflow occur it may not be possible for the water in the boiler to be immediately evaporated (or transferred into surge tank **15** as later described) down to a level corresponding to the required steam output of the boiler as a result of closing down the feed water supply valve **42** under the dictates of the rising steam pressure and water level. The steam pressure would then increase beyond the standard and the master loading pressure in pipe **26** would also increase above the standard value. When increased sufficiently above standard, depending upon the adjustment of relay **55**, the blowdown valve **54** will start to open up so as to assist in dropping the level of water in the boiler drum, and thus decrease the rate of steam generation so as to bring the steam pressure back to the normal value.

The loading pressure within the pipe **26** is applied through a branch **26A** to both the A and C chambers of the relay **55**, while the opposing chamber B is left open to the atmosphere. Thus the loading pressure is doubly effective in positioning the supply and bleed valves of chamber D of the relay **55**. The initial spring loading adjustment of the relay is such that pressure within the pipe **26A** is not effective in positioning the valves of the relay **55** until after a predetermined high loading pressure is attained representative of a predetermined high steam pressure. For instance the relay may be so adjusted that for an increase of say 25–35 p. s. i. loading pressure from pilot **25** the output of the relay will cover the range of 5–25 p. s. i. for opening valve **54**. The output pressure from the D chamber of the relay is applied to the diaphragm valve **54** through a pipe **57**. Interposed in the pipe **57** is a selector valve **58** which allows the possibility of hand or automatic control of the valve.

Thus it is seen that the blowdown valve **54** is normally closed, and is opened only under what may be termed an emergency condition of high steam pressure when it is desired to more rapidly relieve water from the boiler drum than is possible by merely shutting off the supply line **10** and waiting for the level to be lowered through evaporation.

In general, the control system of Figs. 1, 2 and 3 provides that the greater the depth of immersion the greater the contact area of the boiler water with the heating unit becomes, and consequently the greater the steaming rate of the unit will be. There is, of course, a desirable maximum and minimum level of water in the boiler not to be exceeded.

The steam pressure controller has two principal functions:

1. To control water level in the boiler and to maintain steam pressure within desired limits at different loads.

2. To open the blowdown valve in the event that the steam pressure increases beyond a predetermined high value. Blowdown valve **54** is normally closed and is opened only upon emergency high pressure.

The water level controller **37** functions to open the feed water valve **42** as rating (steam flow) increases, and subsequently as the operating water level in the generator is increased. Although called a water level controller, its essential function serves primarily to maintain an increase in rate of fresh feed water flow as boiler demand increases, and also to stabilize the action of the steam pressure controller in the operation of the feed water valve.

Water concentration is controlled both by the conductivity controller **21**, operating on the bleed control valve **20**, and by an automatic transfer of boiler water to and from the surge tank **15**. The operation of such automatic transfer, through the agency of valves A—B—C—D, will now be described in connection with Figs. 1, 4 and 5.

Referring first to Fig. 1, it will be noted that a relatively large pipe **16** joins the lower portion of boiler **1** with the bottom of surge tank **15** for fast transfer of water, from the boiler to the tank, or from the tank to the boiler, under control of a quick opening solenoid valve C; the valve C being normally closed but is capable of being quickly fully opened upon energization of its solenoid. By-passing the larger valve C is a smaller valve D (of operational type similar to C) for providing relatively slower transfer of water between the boiler and tank when valve C is closed and valve D is opened.

The mere opening of valves D or C does not of itself cause water to pass between the boiler and tank. The transfer is accomplished through relationship of static pressure in the boiler and tank, and relationship in static head between the liquid levels in the boiler and tank. Pressure communication between the two is through a pipe **19** joining the steam space of boiler **1** with the

top of tank 15 and controlled by solenoid actuated quick opening valve A, which is normally closed when its solenoid is deenergized. The top of tank 15 may be vented to an area of lower pressure through the agency of solenoid actuated quick opening valve B, which is normally closed when its solenoid is deenergized.

The following operations of transfer are accomplished:

1. With valves A and C open, valves B and D closed. Pressure is equalized between boiler and tank. The additional static head of water in tank 15 over that of boiler 1 causes a "Fast" transfer of water from tank to boiler (passed through large valve C).

2. With valves A and D open, valves B and C closed. "Slow" transfer of water from tank to boiler.

3. With valves B and C open, valves A and D closed. The tank 15 is vented to atmosphere. The higher pressure in boiler 1 causes a "Fast" transfer of water (passed through valve C) from boiler to tank.

4. With valves B and D open, valves A and C closed. "Slow" transfer of water from boiler to tank.

5. All valves closed. No transfer in either direction.

The above noted valve combinations, with resulting conditions of water transfer, are desirably accomplished upon predetermined combinations of operating conditions as tabulated in Fig. 4.

The control so far described provides:

1. A control of feed water input rate to vary the electrode immersion with demand, limiting the effect from pressure (both high and low) so that water level will dominate the inflow and not allow an excessive high or low level; responsive to steaming demand (steam pressure and steam flow rate), actual water level (immersion) and with a check on actual water flow rate against the dictated rate.

2. A control of conductivity of the pool water so that the steaming rate is in direct relation to immersion, first by a bleed from the pool under the control of a conductivity cell, and secondly to counteract the temporary adverse effect upon the conductivity of the pool, such as temperature and concentration dilution of pool by sudden increase in rate of feed upon increasing demand might cause, through supplementing the bleed control with a transfer of water from boiler to tank, or vice versa.

3. Protection against extreme high level in the boiler, by steam pressure opening an emergency blowdown through the agency of a doubling relay.

The present water transfer system supplements previous control by a temporary transfer of water between the tank and boiler, and also to protect against excessive high or low levels in the boiler.

To accomplish operation of the transfer valves we provide electric contacts in the steam pressure controller 23, the boiler water level controller 37 and the tank level controller 41. Specifically, the Bourdon tube 23, sensitive to steam pressure, positions a contact arm 59 to close circuit with a terminal 60 when the steam pressure reaches a predetermined high pressure, or to close circuit with a terminal 61 should steam pressure reach a predetermined low pressure; beyond which pressures it is not desired operate.

We provide the boiler water level controller 37 with a contact arm 62 arranged to close circuit with a terminal 63 when maximum permissible immersion of the electrode is reached, or to close circuit with a terminal 64 when minimum permissible immersion of the electrodes is reached.

The tank level controller 41 has a contact arm 65 arranged to cooperate with three contact terminals 66, 67 and 68. The parts 66 and 67 are of an elongated nature spanning the entire angular travel of the arm 65 except for a non-contacting gap corresponding to a liquid level equivalent of about ±2 inches across the center of the surge tank. In other words, the actual level of water within the tank 15 may fluctuate from 2 inches above the tank center to 2 inches below the tank center without the contact arm 65 engaging either 66 or 67. Should the level fall more than 2 inches below the center of the tank, then arm 65 engages 66 and maintains such engagement for all levels below. On the other hand, should the level rise 2 inches above the center of the tank, the arm 65 engages 67 and maintains such engagement for all levels up to a full tank. When the level reaches "full" the arm 65 additionally engages terminal 68 for a purpose to be explained.

Referring now particularly to Fig. 4, it will be noted that water transfer between boiler and tank, through control of valves A—B—C—D, is dictated by (1) the extent of electrode immersion, (2) value of steam pressure, and (3) the amount of water in the storage tank or conversely the available space within the storage tank to accept water from the boiler.

Considering first the electrode immersion, it will be observed from Fig. 4 that three general conditions may exist.

1. When the water level within the boiler is in what we term the "operating range," i. e. between the points 35, 36, no emergency level condition exists within the boiler and water from the boiler may be transferred to the tank, or may be returned to the boiler from the tank, under the dictates of steam pressure and tank water level.

2. If the level of water within the boiler reaches the maximum immersion limit the arrangement is such that no additional water can be transferred to the boiler from the tank.

3. Should the water level within the boiler reach the minimum immersion limit, then no water may be transferred from the boiler to the tank.

Considering next the effect of steam pressure variations, it will be observed that in general a high steam pressure calls for transferring water from the boiler to the tank so as to decrease the immersion of the electrodes and thereby the steaming possibility. An exception is when the electrodes are already at their minimum immersion limit. If steam pressure is lower than normal, then the tendency is to increase the immersion of the electrodes by transfer of water from the tank to the boiler; except for a condition of where the maximum immersion of the electrodes already exists.

Considering now the level of liquid within the tank, as a variable for the purpose of transfer control, it will be observed that four conditions are shown in Fig. 4, namely, the normal desired level at a point ± 2 inches across the middle of the drum, a high or a low operating condition, and a full tank condition.

The indication of "high" or "low" level within the tank is not a condition of emergency or calling for drastic action. It is quite possible that the liquid within the tank may be con-

sidered as "high level" and still there be available space within the tank for storing water from the boiler. Conversely, the condition may be indicated as "low tank level" and still there may be some water in the tank for possible transfer to the boiler. The only emergency condition in connection with the tank level is when the tank is "full," for then it is important that no more water be moved from the boiler to the tank which might cause the tank to overflow through valves A or B. Valve B usually vents to an area of lower pressure rather than to waste or the atmosphere, and thus damage to the equipment might be effected were tank 15 filled to an extent that water would pass through the valve B.

No damage to equipment is expected should the tank 15 be emptied, and therefore no emergency "empty" condition is provided for.

The particular function of the transfer system just described is in providing a storage place wherein water, at the temperature and concentration of the boiler pool, may be stored for quick return to the boiler when needed. In other words, to take care of sudden, rapid demand swings or surges upon the boiler steaming capacity, through moving hot concentrated water from the boiler to the tank for storage when not needed, and for returning it to the boiler quickly when needed. The latter operation obviates dilution of the water in the vaporizing pool by sudden inflow of raw feed water at a relatively lower temperature and relatively lower value of conductivity. While the long range variation in rate of feed input, to accommodate basic changes in rate of operation, is accomplished through regulation of the feed input valve 42, as previously described, the transfer system, including the storage tank 15, acts with a flywheel effect to take care of rapid variations in demand upon the steaming capacity of the boiler.

Following any surge in demand, such as an increase or decrease in steam demand, with corresponding decrease or increase in steam pressure, upon the occurrence of which hot, high concentration water is transferred between the boiler and tank, the valves should be so positioned as to accomplish a slow return to or from the surge tank to always tend to return the liquid level within the tank to its mid point.

On the premise that steaming capacity bears a direct relation to extent of electrode immersion, it is apparent that this is in turn based upon holding the conductivity of the water in the vaporizing pool substantially uniform. Sudden increases in rate of steam outflow will call for an increased rate of feed water with consequent dilution of the pool water, both as to temperature and conductivity, which effects are adverse to increasing the steam generation rate. Through our invention, however, we tend to avoid such adverse conditions by taking care of sudden surges in demand through transfer of hot highly concentrated water to or from the storage tank.

Immediately following such a surge, with consequent transfer of water between the boiler and the tank, we so control the transfer valve system as to tend to return the tank level to its mid point in anticipation of another demand upon the tank for water or for storage space. Thus, referring to Figs. 4 and 5, the valving arrangement is such as to always tend to return the surge tank level to its mid position.

In the transfer system as illustrated and described, all instrument contacts are normally open and the valves A—B—C—D are normally closed when their solenoids As—Bs—Cs—Ds are deenergized. Desirably, when valve A is open, valve B is closed, and vice versa. When valve C is open, for rapid transfer of water, valve D is also open. When maximum immersion limit is reached we never transfer water from the tank to the boiler, and conversely, when minimum immersion limit is reached we never transfer water from the boiler to the tank. When the water level within the boiler is within the normal operating range we may transfer water either way but always follow a demand surge by a transfer tending to return the level within the surge tank to mid-point.

It is not believed necessary to go into detailed explanation of how the electric circuit of Fig. 5 accomplishes the various combinations tabulated in Fig. 4. It is believed that this is self-explanatory for the various combinations of boiler electrode immersion, steam pressure, and tank water level. Suffice it to describe a single set of conditions to illustrate how the circuits of Fig. 5 will accomplish the valve combinations of Fig. 4.

Consider operating condition #19 of Fig. 4 where the boiler electrode immersion is in its "operating range." Steam pressure is at a "normal" value. Under such conditions neither the contact arm 62 nor the contact arm 59 is engaging a terminal 63, 64 or 60, 61 and the respective relays R1, R2, R3 and R4 remain in the deenergized condition as shown in Fig. 5. The level of the water within the tank is at the "mid±2 inch" position and the contact arm 65 is not engaging any of the terminals 66, 67 or 68. Operation is completely normal in every respect in that the boiler electrode immersion is satisfactory for the demand and thus the rate of vaporization is such as to maintain uniform normal steam pressure. Furthermore, the storage tank 15 is approximately one-half full. As seen in Fig. 4, there is no transfer of water in either direction through the pipe 16. Valves B, C and D are closed, while valve A is opened for pressure equalization between the boiler and the storage tank. All of the electrical circuits in connection with the four valves are as shown in Fig. 5 with the solenoid windings Bs, Cs and Ds deenergized while the winding As is energized.

Assume now that boiler electrode immersion is in the desired "operating range," but apparently is slightly higher than that corresponding to the rate of steam demand so that steam pressure is "high." As illustrated in Fig. 4, unless the storage tank 15 is "full" (condition #13) there will be a fast transfer of water from the boiler to the tank (conditions 14, 15 or 16) in order to reduce the extent of immersion, and thus the rate of steam generation, to thereby decrease the "high" steam pressure to its desirable "normal" value.

On the other hand, if the boiler electrode immersion is in the desired "operating range," but slightly lower than that corresponding to the rate of steam demand, the steam pressure may be "low." Under this condition (operating conditions 21, 22, 23, 24) the valve positions dictate a "fast" transfer of water from the tank to the boiler, regardless of tank level, to increase electrode immersion and thereby increase vaporization, and raise steam pressure.

In like manner, the possible operating conditions may be traced in Fig. 4, to indicate the open or closed positions of valves A—B—C—D,

with resulting direction and speed of water transfer between boiler and tank.

While we have illustrated and described certain preferred embodiments of our invention, it will be understood that this is by way of explanation only and not to be considered as limiting.

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

1. The method of operating a steam generator of the type having two interconnected pressure chambers in one of which electric energy is dissipated in a water pool for vaporizing the water, which includes, controlling the supply of feed water directly to the water pool chamber responsive to a plurality of variables in the operation of the generator, and automatically transferring liquid from one chamber to another when at least one of the variables reaches a predetermined value.

2. The method of operating a steam generator of the type having two interconnected pressure chambers in one of which electric energy is dissipated in a water pool for vaporizing the water, which includes, controlling the rate of supply of feed water directly to the water pool chamber conjointly responsive to demand upon the unit and to the amount of water in the pool, and automatically transferring water from one chamber to another when one of the feed water control variables reaches a predetermined value.

3. The method of controlling the operation of an electric steam generator of the type having two interconnected pressure chambers in one of which electric energy is dissipated in a water pool for vaporizing the water, which includes, feeding one of the chambers with water to form a pool in which the electrodes are immersed for vaporizing the water, determining the extent of immersion, obtaining a representation of the steam demand upon the unit, continuously utilizing the values of these two variables in controlling the rate of feeding of water to the pool, and transferring water from one chamber to the other when one of the variables reaches a predetermined value.

4. The method of controlling the operation of an electric steam generator of the type having two interconnected pressure chambers in one of which electric energy is dissipated in a water pool for vaporizing the water, which includes, feeding one of the chambers with water to form a pool in which the electrodes are immersed for vaporizing the water, determining the extent of immersion, obtaining a representation of the steam demand upon the unit, continuously determining the rate of supply of feed water to the unit, continuously utilizing the values of these three variables in controlling the rate of feeding of water to the unit, and transferring water from one chamber to another when at least one of the three variables reaches a predetermined value.

5. The method of claim 4 wherein the transfer of water is from the pool chamber to the second chamber when the value of the mentioned variables dictate that water should be removed from the pool, and transferring from the second chamber to the pool chamber when the variables dictate that the pool should be increased.

6. The method of operating an electric steam generator of the type having two interconnected chambers in one of which electric energy is dissipated in a water pool for vaporizing the water and the other chamber providing water storage, which includes, controlling the conductivity of the pool water by a bleed of water from the pool responsive to a measure of conductivity, and supplementing such bleed by transferring water from one chamber to the other upon change in unit load.

7. The method of claim 6 wherein the transfer of water is from storage chamber to pool chamber upon sudden increase in demand to temporarily counteract any adverse dilution of pool water such as would be caused by sudden increase in rate of feed supply responsive to increased unit load demand.

8. The method of claim 6 including the further step of protecting the unit against over-immersion of the electrodes through the opening of an emergency blowdown responsive to steam pressure.

9. The method of operating an electric steam generator of the type having two interconnected chambers in one of which electric energy is dissipated in a water pool for vaporizing the water and the other chamber providing water storage, which includes, normally feeding water to the pool chamber in accordance with load demand in a manner such that electrode immersion is within predetermined high and low limits, and supplementing the feed by transferring water from one chamber to another responsive to steam pressure and storage chamber water level.

10. The method of claim 9 including the step of preventing transfer of water from the storage chamber to the pool chamber when maximum immersion of the electrodes in the pool chamber is reached.

11. The method of claim 9 including the step of preventing transfer of water from the pool chamber to the storage chamber when minimum immersion of the electrodes in the pool chamber is reached.

12. The method of claim 9 in which normally water is transferred from the pool chamber to the storage chamber responsive to predetermined high steam pressure to thereby decrease the immersion of the electrodes and thus the steaming rate.

13. The method of claim 9 in which normally water is transferred from the storage chamber to the pool chamber responsive to predetermined low steam pressure to thereby increase the immersion of the electrodes and thus the steaming rate.

14. The method of claim 9 in which, following a load change, the water content of the storage chamber is returned toward a predetermined normal value.

15. In combination with an electric steam generator having two interconnected pressure chambers in one of which are electrodes and having provisions for supplying feed water to the electrode chamber to form a pool in which the electrodes are variably immersed for vaporizing the water, means sensitive to a demand factor on the unit, means sensitive to the amount of electrode immersion, control means responsive to both said sensitive means adapted to regulate the feed water supplying provisions, and transfer means arranged to cause transfer of water from one chamber to another when one of said sensitive means reaches a predetermined value.

16. In combination with an electric steam generator having two interconnected pressure chambers in one of which are electrodes and having provisions for supplying feed water to the electrode chamber to form a pool in which the electrodes are variably immersed for vaporizing the water, first means determining the extent of

immersion, second means determining steam demand upon the unit, third means determining the rate of supply of feed water, means continuously controlling the supply of feed water conjointly responsive to said first three named means, and means adapted to cause a transfer of water from one chamber to another when one of the first three named means reaches a predetermined value.

17. In combination with an electric steam generator having two interconnected pressure chambers in one of which are electrodes and having provisions for supplying feed water to the electrode chamber to form a pool in which the electrodes are variably immersed for vaporizing the water, means regulating the electrode immersion responsive to demand upon the unit, means regulating bleed of water from the pool responsive to conductivity of the pool water, and means adapted to cause a transfer of water from one chamber to another responsive to a variable condition in the operation of the unit.

18. In combination with an electric steam generator having two interconnected pressure chambers in one of which are electrodes and having provisions for supplying feed water to the electrode chamber to form a pool in which the electrodes are variably immersed for vaporizing the water, means regulating bleed of water from the pool responsive to conductivity of the pool water, and means causing a transfer of water from one chamber to the other upon change in unit load.

19. In combination with an electric steam generator having two interconnected pressure chambers in one of which are electrodes and having provisions for supplying feed water to the electrode chamber to form a pool in which the electrodes are variably immersed for vaporizing the water, means establishing a fluid control pressure representative of demand upon the unit, means establishing a fluid control pressure representative of water level within the pool chamber and thereby of the electrode immersion, control means adapted to regulate the rate of supply of water responsive to both said fluid control pressures, valve means controlling transfer of water from one chamber to the other, and transfer means sensitive to a selected variable in the operation of the unit adapted to position said valve means.

20. In combination with an electric steam generator having two interconnected pressure chambers in one of which are electrodes and having provisions for supplying feed water to the electrode chamber to form a pool in which the electrodes are variably immersed for vaporizing the water, means establishing a fluid control pressure continuously representative of electrode immersion, means establishing a second fluid control pressure continuously representative of demand upon the unit, means establishing a third fluid control pressure continuously representative of rate of water supplied to the pool, control means for the water supply to the pool responsive to said three fluid control pressures, valve means controlling transfer of water from one chamber to the other, and a plurality of means separately responsive to steam pressure and electrode immersion and storage chamber water level arranged to conjointly control the said valve means.

21. The method of operating an electric steam generator of the type having two interconnected pressure chambers in one of which electric energy is dissipated in a water pool for vaporizing the water and the other chamber providing water storage, which includes, continuously controlling the extent of immersion of the electrodes in the pool conjointly responsive to steam demand upon the unit and to amount of water in the pool, and continuously controlling the conductivity of the pool water in which the electrodes are immersed by controllably bleeding pool water from the pool chamber and by transferring water between the pool chamber and the storage chamber.

22. The method of operating an electric steam generator of the type having two interconnected pressure chambers in one of which electric energy is dissipated in a water pool for vaporizing the water and the other chamber providing water storage, which includes, continuously controlling the extent of immersion of the electrodes in the pool conjointly responsive to steam demand, amount of water in the pool, and rate of feed water supply to the unit; and continuously controlling the conductivity of the pool water in which the electrodes are immersed by controllably bleeding pool water from the pool chamber and by transferring water between the pool chamber and the storage chamber.

23. The method of operating an electric steam generator of the type having two interconnected pressure chambers in one of which electric energy is dissipated in a water pool for vaporizing the water and the other chamber providing water storage, which includes, continuously controlling the extent of immersion of the electrodes in the pool conjointly responsive to steam pressure, rate of steam outflow, extent of electrode immersion, and rate of feed water supply to the unit; and continuously controlling the conductivity of the pool water in which the electrodes are immersed by controllably bleeding pool water from the pool chamber and by transferring water between the pool chamber and the storage chamber.

24. The method of operating an electric steam generator of the type having two interconnected pressure chambers in one of which electric energy is dissipated in a water pool for vaporizing the water and the other chamber providing water storage, which includes, continuously controlling the extent of immersion of the electrodes in the pool conjointly responsive to a plurality of variables in the unit operation, and continuously controlling the conductivity of the pool water in which the electrodes are immersed by controllably bleeding pool water from the pool chamber and by transferring water between the pool chamber and the storage chamber, the transferring of water from the storage chamber to the pool chamber being prevented when predetermined maximum immersion of the electrodes is reached and the transferring of water from the pool chamber to the storage chamber being prevented when predetermined minimum immersion of the electrodes is reached.

25. The method of operating an electric vapor generator of the type having two interconnected pressure chambers in one of which electric energy is dissipated in a liquid pool for vaporizing the liquid and the other chamber providing liquid storage, which includes, controlling the specific conductivity of the pool liquid by a bleed of liquid from the pool responsive to a measure of specific conductivity of the liquid, and supplementing such bleed by transferring liquid from one chamber to the other upon change in unit load.

26. In combination with an electric vapor generator having two interconnected pressure chambers in one of which are electrodes and having provisions for supplying feed liquid to the electrode chamber to form a pool in which the electrodes are variably immersed for vaporizing the liquid, means establishing a fluid control pressure representative of demand upon the unit, means establishing a fluid control pressure representative of liquid level within the pool chamber and thereby of the electrode immersion, control means adapted to regulate the rate of supply of liquid responsive to both said fluid control pressures, valve means controlling transfer of liquid from one chamber to the other, and transfer means sensitive to a selected variable in the operation of the unit adapted to position said valve means.

27. In combination with an electric vapor generator having two interconnected pressure chambers in one of which are electrodes and having provisions for supplying feed liquid to the electrode chamber to form a pool in which the electrodes are variably immersed for vaporizing the liquid, means establishing a fluid control pressure continuously representative of electrode immersion, means establishing a second fluid control pressure continuously representative of demand upon the unit, means establishing a third fluid control pressure continuously representative of rate of liquid supplied to the pool, control means for the liquid supply to the pool responsive to said three fluid control pressures, valve means controlling transfer of liquid from one chamber to the other, and a plurality of means separately responsive to vapor pressure and electrode immersion and storage chamber liquid level arranged to conjointly control the said valve means.

28. The method of operating a steam generator of the type having two interconnected pressure chambers in one of which electric energy is dissipated in a water pool for vaporizing the water, which includes, controlling the rate of supply of feed water directly to the water pool chamber conjointly responsive to steam outflow rate and to the amount of water in the pool, and automatically transferring water from one chamber to another when one of the feed water control variables reaches a predetermined value.

29. The method of operating an electric steam generator of the type having two interconnected chambers in one of which electric energy is dissipated in a water pool for vaporizing the water and the other chamber providing water storage, which includes, normally feeding water to the pool chamber in accordance with steam outflow rate in a manner such that electrode immersion is within predetermined high and low limits, and supplementing the feed by transferring water from one chamber to another responsive to steam pressure and storage chamber water level.

30. The method of operating an electric steam generator of the type having two interconnected pressure chambers in one of which electric energy is dissipated in a water pool for vaporizing the water and the other chamber providing water storage, which includes, continuously controlling the extent of immersion of the electrodes in the pool conjointly responsive to steam outflow rate from the unit and to amount of water in the pool, and continuously controlling the conductivity of the pool water in which the electrodes are immersed by controllably bleeding pool water from the pool chamber and by transferring water between the pool chamber and the storage chamber.

31. The method of operating an electric steam generator of the type having two interconnected pressure chambers in one of which electric energy is dissipated in a water pool for vaporizing the water and the other chamber providing water storage, which includes, continuously controlling the extent of immersion of the electrodes in the pool conjointly responsive to steam outflow rate, amount of water in the pool, and rate of feed water supply to the unit; and continuously controlling the conductivity of the pool water in which the electrodes are immersed by controllably bleeding pool water from the pool chamber and by transferring water between the pool chamber and the storage chamber.

32. In combination with an electric steam generator having two interconnected pressure chambers in one of which are electrodes and having provisions for supplying feed water to the electrode chamber to form a pool in which the electrodes are variably immersed for vaporizing the water, means sensitive to steam outflow rate from the unit, means sensitive to the amount of electrode immersion, control means responsive to both said sensitive means adapted to regulate the feed water supplying provisions, and transfer means arranged to cause transfer of water from one chamber to another when one of said sensitive means reaches a predetermined value.

33. In combination with an electric steam generator having two interconnected pressure chambers in one of which are electrodes and having provisions for supplying feed water to the electrode chamber to form a pool in which the electrodes are variably immersed for vaporizing the water, means establishing a fluid control pressure representative of steam outflow rate from the unit, means establishing a fluid control pressure representative of water level within the pool chamber and thereby of the electrode immersion, control means adapted to regulate the rate of supply of water responsive to both said fluid control pressures, valve means controlling transfer of water from one chamber to the other, and transfer means sensitive to a selected variable in the operation of the unit adapted to position said valve means.

34. In combination with an electric steam generator having two interconnected pressure chambers in one of which are electrodes and having provisions for supplying feed water to the electrode chamber to form a pool in which the electrodes are variably immersed for vaporizing the water, means establishing a fluid control pressure continuously representative of electrode immersion, means establishing a second fluid control pressure continuously representative of steam outflow rate from the unit, means establishing a third fluid control pressure continuously representative of rate of water supplied to the pool, control means for the water supply to the pool responsive to said three fluid control pressures, valve means controlling transfer of water from one chamber to the other, and a plurality of means separately responsive to steam pressure and electrode immersion and storage water level arranged to conjointly control the said valve means.

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