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2,612,592

CONTROL SYSTEM FOR ELECTRIC STEAM GENERATORS

Filed Oct. 3, 1950

3 Sheets-Sheet 1

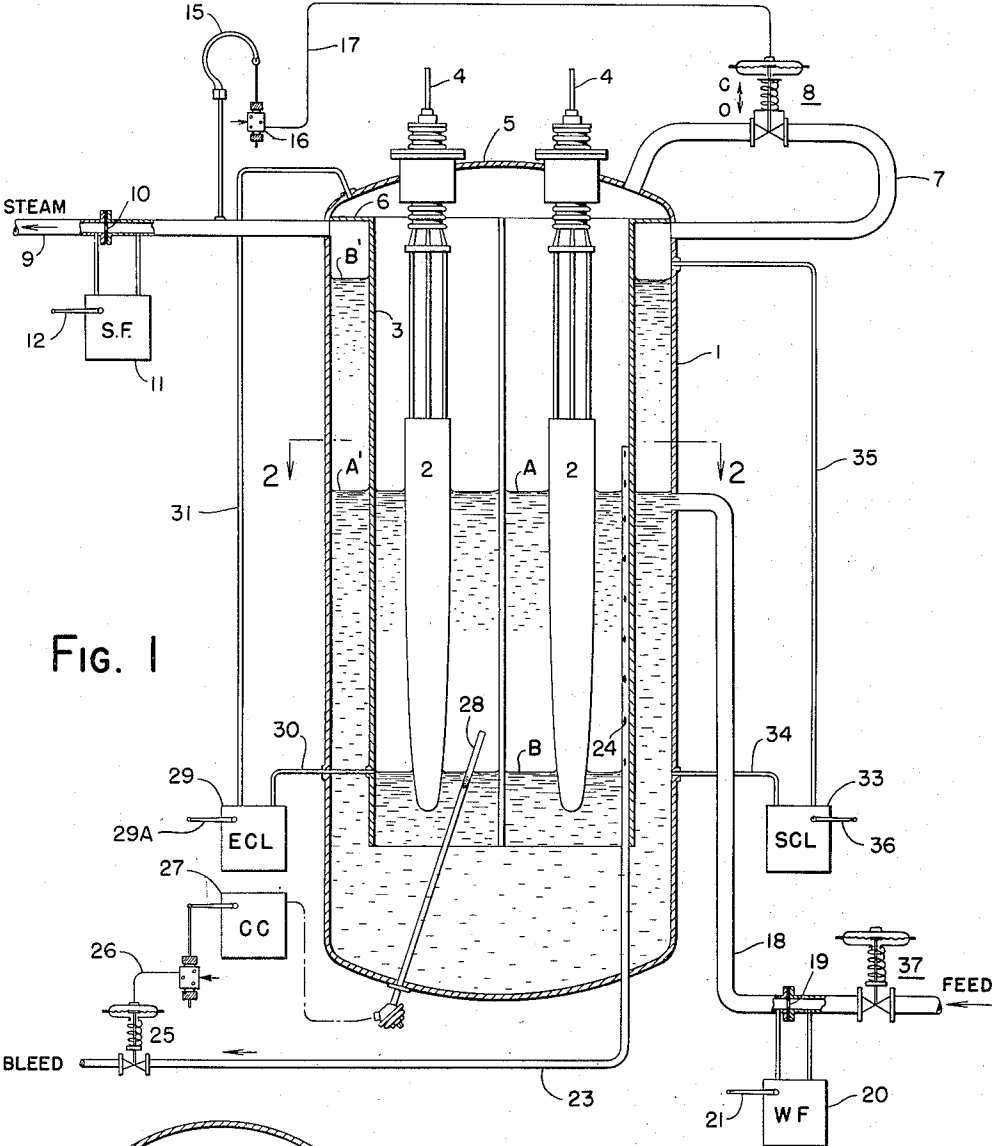


FIG. 1

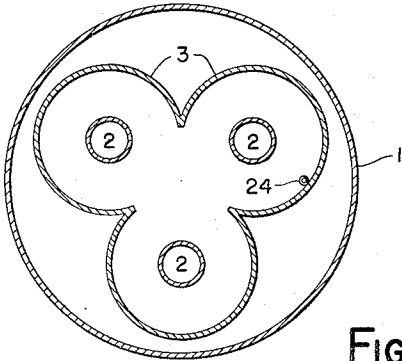


FIG. 2

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3 Sheets-Sheet 2

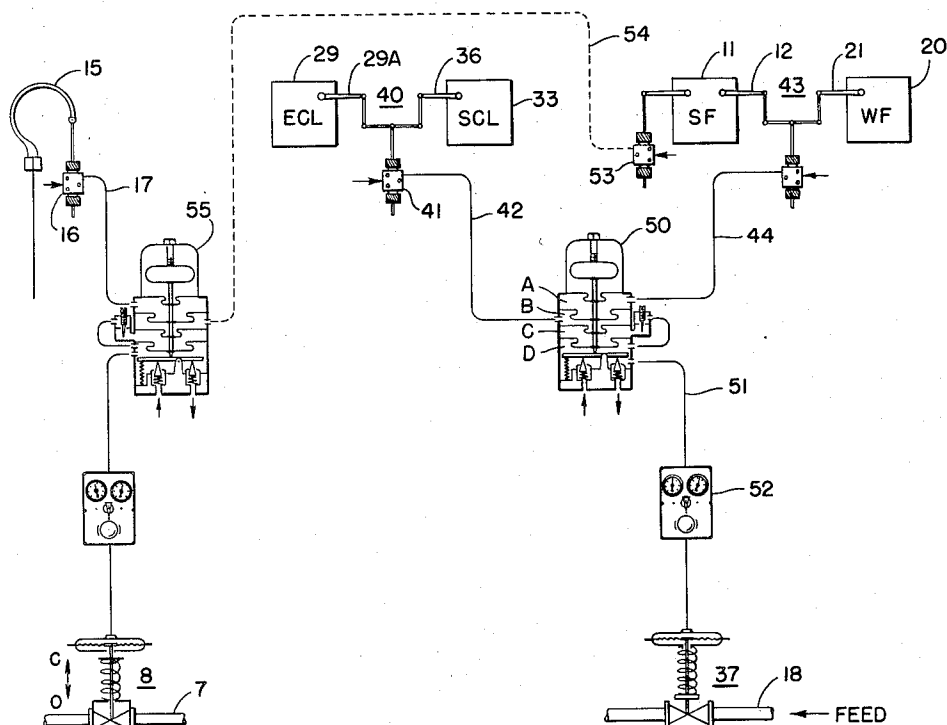


FIG. 3

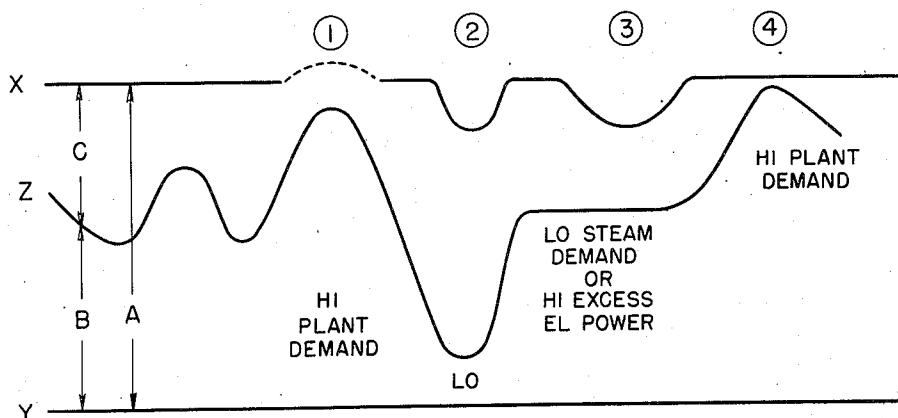


FIG. 5

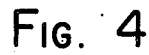
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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,612,592

CONTROL SYSTEM FOR ELECTRIC STEAM GENERATORS

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Application October 3, 1950, Serial No. 188,118

37 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 optimum value under existing demand conditions and with full safety to life and apparatus.

The problem 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 liquid levels, as well as the conductivity of the liquid within the unit, all in proper degree so that the vapor which is generated will satisfy the demand while maintaining desired conditions of 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 a 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 electrode chamber. The specific resistance of the water is a function of the concentration or amount of dissolved solids in the water and also of 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 electrode chamber.

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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 electrode chamber 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 electrode chamber, the 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 water 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 electrode chamber 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 steam demand indicates a desirability of raising the level of water within

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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 the 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. In the past the storage or surge chamber has been entirely separate from the main shell of the generating unit and usually has been located at an elevation somewhat above the electrode chamber. The water stored within the generator proper includes both the water within the cloverleaf neutral plate and also that water between the cloverleaf plate and the shell of the generator. The latter water unnecessarily adds to the volume of water to be stored in the external surge tank because the load regulation only requires a variation of water within the cloverleaf and surrounding electrodes.

It has been proposed that the space between the cloverleaf and the outer shell be closed at the top and thus have such space comprise a surge or storage chamber in U-tube connection around the bottom of the cloverleaf plate with the electrode chamber proper. It is to a unit of this general construction that our present invention is applied.

It is an object of our invention to provide both method and apparatus 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.

Still another object is to provide a method and apparatus of control of an electric-vapor generator having a vaporizing chamber and storage chamber concentrically arranged within the pressure shell of the unit.

Still another object is to provide method and apparatus for controlling such a vapor generator to keep the total amount of water in the two chambers substantially constant during different rates of operation and for various levels within the two chambers.

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

In the drawings:

Fig. 1 is a diagrammatic sectional elevation of the general type of electric-steam generator to which the invention is applied.

Fig. 2 is a diagrammatic sectional view of Fig. 1 in the direction of the arrows 2-2.

Fig. 3 diagrammatically illustrates a pneumatic control system for the generator of Figs. 1 and 2.

Fig. 4 illustrates a modification of the system of Fig. 3.

Fig. 5 is a graph in connection with Fig. 4.

Referring to the drawing, the particular unit to be described and to which our control is ap-

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plied includes a vertically mounted drum or pressure vessel 1 supported in customary manner (not shown). Insulated through the upper head 5 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 enclosed by a cloverleaf neutral plate 3 properly spaced from the electrodes and from the inner surface of the pressure drum 1. The terminals 4 of the electrodes are connected through the necessary electrical apparatus to a source of electrical power (usually 3-phase); the arrangement forming no part of the present invention.

Fig. 2 is a somewhat diagrammatic sectional view taken through the assembly of Fig. 1 and shows the general arrangement of the drum 1, the electrodes 2, and the neutral plate 3.

The cloverleaf shaped neutral plate 3 is joined to the shell 1, near the upper head 5, by a plate 6, thus dividing the unit into two chambers. The electrode chamber is enclosed by the cloverleaf 3 and the drum head 5 as well as the top of plate 6. The storage chamber is formed between the inner wall of the shell 1 and the outer wall of the cloverleaf 3 as well as the bottom of plate 6. Communication of the electrode chamber with the storage chamber is had around the open lower end of the cloverleaf 3. When the unit is not operating and all parts are at atmospheric pressure any water within the unit will find a common level within the two chambers. During operation the level within the storage chamber may be the same as that within the electrode chamber or may differ therefrom as will be pointed out hereinafter.

The uppermost steam space of the storage chamber is joined to the steam space of the electrode chamber by a pipe 7 having therein a control valve 8 of the spring loaded pneumatically actuated type. A steam outflow pipe 9 joins the steam space of the storage chamber. Steam which is generated within the electrode chamber passes through the pipe 7 and valve 8 into the steam space of the storage chamber from which steam passes through the pipe 9 to a point of usage. Such outgoing steam passes an orifice 10 across which is connected a steam flow (SF) meter 11 arranged to continually position an arm 12 representative of rate of steam outflow through the pipe 9.

Connected to the pipe 9 is a Bourdon tube 13 arranged to position the movable element of a pilot valve 16 for continually establishing in a pipe 17 a fluid loading pressure representative of static pressure of the steam in the outgoing conduit 9.

Water is supplied to the unit through a pipe 18 which enters the shell 1 at a considerable elevation above the bottom of the electrodes. In the pipe 18 is an orifice 19 across which is connected a water flow (WF) meter 20. Meter 20 is arranged to position an arm 21 continually representative of rate of supply of feed water to the unit.

By entering the raw feed water to the storage chamber at an elevated location, the raw water, of lower temperature and reduced conductivity, is diffused through the water of the storage chamber and heated thereby before it turns the lower end of the partition 3 to enter the electrode chamber. A pneumatic control valve 37 is shown in pipe 18 for regulating the rate of supply of feed water.

As previously mentioned, the vaporization of

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water within the unit leaves dissolved or entrained salts or solids in the water pool and thus the concentration of the water into the two chambers would continually build up to an undesirable value. It is advisable to have a controllable bleed of the most highly concentrated water and to this end we provide a pipe 23 which enters the lower portion of the shell 1 and passes upward within the electrode chamber being tack-welded to the inner wall of the cloverleaf partition 3. As indicated at 24 this may be perforated so that bleed water passing outward through the pipe 23 samples vertically the water pool surrounding the electrodes, this being the water which is furthest away from the incoming diluting raw feed water and at the same time being the water which is continually increasing in concentration through evaporation.

In the pipe 23 we show a pneumatically actuated control valve 25 positioned responsive to a loading pressure (in a pipe 26) which is continually established by the meter 27 which is a conductivity meter (CC) having an active element 28 located within the electrode chamber.

At 29 we show an electrode chamber level (ECL) measuring device having pressure pipe connections thereto 30 and 31. The pipe 31 passes through the outer shell 1 and opens through the partition 3 near the lowest expected level of liquid within the electrode chamber. A pipe 31 joins the steam space of the electrode chamber by opening through the head 5. The meter (ECL) is arranged to continually position an arm 29A continually representative of the level of liquid within the electrode chamber.

In similar manner device 33 determines storage chamber level (SCL) and continually positions an arm 35 representative of liquid level within the storage chamber. The device 33 is connected by a pipe 34 opening through the outer shell 1 into the storage chamber at an elevation which preferably may be the same as the connection elevation 30. The pipe 35 opens through the shell 1 in the steam space of the storage chamber above the highest expected liquid level therein.

It will thus be seen that in Fig. 1 we provide certain instrumentalities which are sensitive to variables in the operation of the unit and also provide control or regulating valves.

In Fig. 1 we have shown the pipe 17 joining the diaphragm chamber of the steam throttle valve 8. Thus the Bourdon tube 15, sensitive to pressure of steam in the outflow pipe 9, adjusts the throttle opening of control valve 8 regulating communication between the steam spaces of the two chambers.

In operation, the unit is first filled with water to the level A and due to initial lack of pressure in steam offtake 9 the diaphragm motor valve 8 is held in wide open position. Upon delivering electric current to the immersed electrodes 2 steam will be generated within the electrode chamber and collect in the steam space above liquid level A. When full effect of steam is through pipe 7 the electrode chamber level A is about at the level A' of the storage chamber surrounding the electrode chamber. The throttle valve 8 is now wide open and offers substantially no resistance to the steam flow from the electrode chamber through the pipe 7 to the steam space of the storage chamber to the offtake pipe 9. Under this condition both chambers are under about the same steam pressure.

With full load steam demand on the unit the

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electrodes 2 are fully immersed to approximately level A. As the steam demand decreases the discharge flow rate through offtake 9 drops and the fully immersed electrodes then generate too much steam so that the pressure in the steam offtake 9 rises. The throttle valve 8 responds to this higher pressure rise by partially closing. Such partial closure raises the resistance of the valve to steam flow through the pipe 7 into the storage chamber and increases the steam pressure within the electrode generating chamber and thereby depresses the water level in the electrode chamber to a level below A. Further rise in steam pressure in offtake and subsequent further throttling by valve 8 continues to depress the water within the electrode chamber until the portion of the electrodes 2 remaining immersed generate only sufficient steam to maintain the slightly increased pressure in the offtake 9 and a balance is established.

The depressed water level within the electrode chamber displaces water therefrom into the storage chamber and causes a rise in the outer chamber water level. The head representing a difference in water levels between the two chambers is a measure of the steam flow resistance introduced by the throttle valve 8. With minimum steam load on the generator the maximum depression of the water in the electrode chamber is exemplified by low level B and the corresponding level in the storage chamber might be high level B'.

As the unit steam flow again increases the immersion adjusting operation by steam pressure control of valve 8 takes place in reverse. With increased steam demand the pressure in the steam offtake 9 falls, the valve 8 opens and water level in the storage chamber falls. The resulting greater immersion of the electrodes 2 generates more steam until the balance again occurs where the rate of steam generation by the electrodes is just sufficient to maintain the slightly decreased pressure in offtake 9.

In order to fully utilize the storage space effectively at all ratings and particularly at maximum rating it is necessary to maintain a substantially constant volume of water within the unit as a whole. To accomplish this means must be provided to feed water into the unit in amount equal to the steam offtake plus bleed. Furthermore the conductivity of the water within the unit should preferably be maintained substantially constant so that steam generated will be proportional to electrode immersion and that maximum output may be realized with maximum electrode immersion.

Due to the cross-section of the electrode chamber water and of the storage chamber water possibly being different at different elevations and different the one from the other, it is not usually possible to measure the level of one chamber or the other as representative of both. Preferably we provide instrumentalities continually adding the two levels as representative of the total amount of water in the unit. When the level is the same in both chambers the two meters ECL and SCL will read the same. As water level decreases in one chamber it increases in the other but not necessarily in the same proportion. The meters may be calibrated to take into account the areas of the two chambers at different levels. The continuous totalizing of the values from the meters ECL and SCL gives a representation of total water in the unit and of any departure from predetermined desirable amount.

Reference will now be had to Figs. 3, 4 and 5 which illustrate preferred arrangements of the instruments and control valves for controlling the operation of the unit.

The arrangement of Fig. 3 shows the meters ECL and SCL interconnected by mechanical linkage 40 for positioning the movable element of a pneumatic pilot valve 41 to continuously establish in the pipe 42 a loading pressure representative of total liquid within the unit.

We show the steam flow meter SF and the water flow meter WF in Fig. 3 as interconnected by mechanical linkage 43 continually comparing the rate of inflow of feed water with the rate of steam outflow through the pipe 9. When the feed water rate is equal to or in desired proportion to the steam flow rate a predetermined loading pressure is established within a pipe 44. The linkage 43 is preferably adjusted to continually compensate for the bleed rate which is under control of the meter CC and preferably is substantially constant and equals a very small percentage of the total rate of water supplied. The system provides a three-element control of feed water to match steam flow against water flow, readjusted by water level or total amount in the unit.

The pneumatic loading pressure established in the pipe 44 is effective within the A chamber of a standardizing relay such as is disclosed and claimed in the Dickey Patent 2,098,913. To the B chamber of the relay is applied the loading pressure in the pipe 42.

After the various elements of the control system are adjusted, in connection with the actual operating unit, the loading pressure within the pipe 44 will have a predetermined value at all times when the water flow rate and the steam flow rate are in desired proportions. Such proportion would be one of equality between the two flow rates were it not for the continuous bleed of water from the pool. Inasmuch as the bleed constitutes such a relatively small portion of the total inflow rate, and variations in the bleed flow are correspondingly of a relatively minute proportion of the inflow rate, the bleed flow may be considered as a constant rate and the linkage 43 biased by that amount. Thus the desired relation between water inflow and steam outflow would be one of equality slightly biased to take into account the predetermined uniform rate of bleed. At any time when this optimum relation exists between the inflow water rate and the steam outflow rate the linkage 43 will establish in the pipe 44 a predetermined air loading pressure.

Under optimum operating conditions the total amount of water in the unit, namely, the sum of the water in the electrode chamber and that in the storage chamber, will be a predetermined amount and for that amount the meters 29 and 33, acting through the linkage 40, will establish in the pipe 42 a predetermined air loading pressure.

Under these optimum conditions the algebraic sum of the effects of the pressures in the A and B chambers of the relay 50 and of the loading spring of the relay will be in equilibrium. Should the water inflow rate or steam outflow rate depart from desired proportionality the loading pressure effective within the A chamber will be greater or less than the optimum value and the relay 50 will vary the loading pressure within the pipe 51 effective upon the motor of the valve 37 for adjusting the latter to vary the rate of water inflow through the pipe 18 in proper direction to

return the water flow rate and steam flow rate to optimum proportionality.

If, on the other hand, the total amount of water in the unit varies from optimum value then the pneumatic loading pressure within the pipe 42 will be increased or decreased from its optimum value and the equilibrium of the relay 50 will be disturbed whereby the valve 37 will adjust the rate of water inflow to return the total amount of liquid within the unit to the desired value.

Located in the pipe 51 is a manual-automatic selector valve 52 providing the possibility of removing the feed water control from automatic and remotely positioning the valve 37 by manual dictates.

It will be appreciated that the system being described includes three separate portions simultaneously operating to control the unit as a whole. These are the steam outflow pressure control of the throttling valve 8, the just described three-element control of feed water inflow, and the conductivity control of the bleed valve 25. The three portions cooperate and are simultaneously effective to regulate the unit as a whole.

In Fig. 3 we may additionally introduce into our control system an element of load upon the unit as represented by steam flow rate. The steam flow meter 11 is arranged to also position the movable element of a pilot valve 53 to continually establish in the pipe 54 a pneumatic loading pressure representative of steam outflow rate. The pipe 54 is connected to the B chamber of a standardizing relay 55 to the A chamber of which is connected the pipe 17. Thus the relay 55 receives a pressure representative of steam pressure in the outflow pipe 9 and also a loading pressure representative of rate of steam flow through the pipe 9. The throttling valve 8 is thus positioned in general in consonance with steam outflow rate and with readjustment depending upon deviations of steam outflow pressure from optimum value.

In Fig. 4 we show another pneumatic control system arrangement incorporating certain of the features of the system of Fig. 3 and in addition further features of our invention. Like parts carry like reference numerals. The conductivity control of the bleed as well as the three-element control of the feed water inflow rate remain the same as described in connection with Fig. 3. However, here the control of the throttle valve 8 includes, in addition to steam pressure effect, certain advantageous effects from other variables of the system.

We illustrate in Fig. 4 the electrode chamber level device 29 arranged to position the movable element of a pilot valve 60 continuously establishing in a pipe 61 a loading pressure representative of liquid level within the electrode chamber. The pipe 61 joins the B chamber of a relay 62, to the A chamber of which is connected the pipe 17. The output of the relay 62 is effective in a pipe 63 which joins the A chamber of a relay 64. The relays 62 and 64 may be termed "limiting relays" and are of a type disclosed and claimed in the Gorrie Reissue Patent Re. 21,804.

At 65 we indicate an electric load determining controller arranged to position the movable element of a pilot 66 to continuously establish in a pipe 67 a pneumatic loading pressure representative of total electrical load demand by the entire plant to which the present steam generator supplies steam. In the particular embodiment being described the electric load to which the controller 65 is sensitive includes not only the electric cur-

rent dissipated in the unit 1 but also the electric demand of the rest of the plant or factory. It is appreciated that for certain installations and conditions the electric load controller 65 may be sensitive only to the electric current demand of the vapor generating unit 1 per se.

In the particular installation being described, and referring now to Fig. 5, the total plant electrical demand may be represented by the line X above a base Y and where the total electrical demand A at any instant is the sum of the demands B and C.

In the present instance it is desired to maintain substantially constant an electric demand rate upon the entire plant to take advantage of a demand rate schedule. While the demand schedule may allow deviations from a base demand rate of a relatively short time interval, it is desired to hold the total power to the plant at a substantially constant rate. This total demand rate X, as previously mentioned, is made up not only of electrical demand of the present vapor generator but also of the other electrical demands throughout the plant. Inasmuch as the plant demand has preference it will be appreciated that the vapor generating unit must be so controlled as to utilize only the remaining portion C of the total electrical demand A at any given time. Thus, the control of the steam throttling valve 8 is primarily under the control of the electric load controller 65 with readjustment factors effective from the steam pressure pilot 13 and from the electrode chamber level pilot 60.

The steam throttle valve 8 is of a spring closing type. When this valve closes the differential pressure lowers the water in the electrode chamber, while raising the water in the storage chamber, and therefore less steam is produced. When the valve opens the level of water in the electrode chamber tends to equalize with the level of water in the storage chamber thus permitting more water in the electrode chamber and generating more steam. Therefore the rate of steam generation will be determined by the electric load controller 65 in order to hold a constant electrical demand on the entire plant. Steam will be produced in accordance with the available electrical power and it will be necessary to use other boilers fuel fired for maintaining a constant steam pressure on the plant system if that is desired. The use of such fuel fired vapor generators and possible tie in of same with the plant forms no part of the present invention.

The output of the relay 64, through a pipe 70, passes through a three-way valve 71 to a pipe 72 effective upon the A chamber of a standardizing relay 73. The output of the relay 73 is effective through a pipe 74 to control the steam throttle valve 8.

We do not wish to have too high a level around the electrodes. If valve 8 becomes wide open we can only equalize the two chambers and if the three-element feed water supply is correct, which essentially maintains a constant total of the two levels, it seems impossible to get a higher level in the electrode chamber than is desired. However, there is a possibility of getting too low a level around the electrodes and this would produce an arcing or burning effect at the base of the electrodes due to high an electrical energy flow for too small an area. This preferably should not go below 8" minimum submersion. The controller 29, sensitive to liquid level in the electrode chamber, is therefore equipped with the pilot 60 which, through the relay 62, will readjust the valve 8.

If the electric generator load drops to too low a point the electrode level controller 29 will act as a limiting device upon the valve 8.

There is also a possibility that at certain load conditions there will be more electric current available than the steam demand in the plant and it would tend to build up the steam pressure above the desired total. We have therefore introduced a steam pressure controller 16 which will, through the relay 62, act upon the relay 64 to tend to close off the steam output by closing the valve 8. There may be times when the steam load is not sufficient to support the energy available from the electric load controller 65. At such times other boilers will not be used and all of the steam will be generated from the electric generator 1. At that time we propose throwing the three-way valve 71 to its alternate dotted position so that the steam pressure controller 16 will serve as a master and the electric load controller 65 will be cut out of service completely.

In case of an exceptionally low level within the electrode chamber or a low electric power, we wish to shut off the unit entirely and therefore we have incorporated a pressure switch 75 and a solenoid three-way valve 76 which will close valve 8 and at the same time be arranged electrically to trip the electric power to the unit.

Under normal operating conditions the steam flow control valve 8 will be controlled directly from the load controller 65 in response to changes in total plant electrical load so as to control the output of the steam generator and thus maintain total plant electrical demand at a constant value regardless of the plant demands for other services. The flow of feed water to the boiler will be controlled by proportioning it to the steam output of the boiler with readjustment of the feed water flow from the total amount of water in the unit. Blow-down will be controlled so as to maintain the conductivity of the boiler water within the desired limits.

In the event that the water level in the electrode chamber falls below a predetermined value the limiting controller 60 will readjust the position of the steam flow control valve 8 so as to prevent the level from getting too low. If the level continues to drop below a predetermined minimum value the pressure switch 75 will operate to trip the electric power off, may sound an alarm, and will open the steam valve 8 wide.

In order to prevent the steam in the main steam header 9 from exceeding a predetermined high limit, steam pressure controller 16 will readjust the position of the steam valve 8 so as to lower the water level in the electrode chamber and thus reduce the steam output of the boiler. There may also be times when the entire plant steam load will be carried by the electric boiler and at such times it will be possible to control the steam pressure by the pressure controller 16 through the manual transfer valve 71.

The principal object of this Fig. 4 system is to maintain a predetermined total power demand X (Fig. 5) on the system through the control of water level, blow-down and steam circulation.

Fig. 5 attempts to indicate various situations in the total plant operation. The base electric power is designated at Y while the desired maximum electric load is the upper line X. The curve Z divides the total electric demand with that portion B being the plant electric demand

while the portion C is that which is available for the steam generator 1. Normally C is within the availability of the generator and the unit operates to hold a constant total demand A. Point 1 illustrates a condition where the electric load required by the plant rises to some value such that the difference between this and the generator demand is so small that it is below the desired minimum of the generator. In that case one of two things must happen. Either the set demand must go up as would normally happen if we didn't use the pressure switch to shut the unit down, or else the pressure switch will shut the unit down and sound an alarm 4. This latter is the desirable situation and point 4 is preferable to point 1. When the unit is shut down it is necessary to start it up by hand as one would a cold boiler and for that reason a manual reset trip on the three-way valve 76 is desirable.

Point 2 represents a low plant demand where the plant load drops to such a low point that the differential between this load and the generator demand exceeds the total allowable on the generator. At this time all that can happen is for the valve 8 to open wide, the level inside the electrode chamber to rise to a given maximum, the electrical load to go to this given maximum. Therefore the actual demand will drop below the set demand until it gets back to some plant load where the differential between it and the set demand is again the maximum of the generator or less. At that time therefore the steam generator will produce its design capacity and no more.

Point 3 illustrates a case where the steam requirements in the plant drop so low that the steam pressure begins to rise above the optimum value. At that time the steam pressure controller 16 will cut back on valve 8 producing less steam and therefore pulling less electrical energy into the steam generator. Here again the demand rate or actual rate on the plant will drop below the demand which is set forth.

It will be understood that the electric load controller 65 may be arranged to be sensitive to the electric demand A or B or C. We have chosen, by way of illustration only, to describe the system of Fig. 5 operating with the electric load controller 65 sensitive to the value A which is in this instance desirably to be maintained constant.

While we have chosen to illustrate and describe certain preferred embodiments of our invention, it will be understood that these are for illustration only and that we are not to be limited thereby.

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

1. 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 determining the amount of water in the two chambers, continuously comparing the rate of steam outflow from the unit with the rate of feed supply to the unit, and continuously controlling the rate of feed supply conjointly responsive to the determining and comparing.

2. The method of claim 1 including 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.

3. 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, maintaining desired conductivity of the pool water in which the electrodes are immersed by controllably bleeding water from the pool, regulating extent of electrode immersion and thereby rate of vapor generation by transferring water between the chambers, and maintaining the total amount of water in the two chambers substantially constant.

4. The method of operating a vapor generator of the type having a plurality of interconnected pressure chambers in one of which electric energy is dissipated in a liquid pool for vaporizing the liquid, which includes, supplying feed liquid under elevated pressure to one of the chambers, regulating extent of electrode immersion and thereby rate of vapor generation by transferring liquid between the chambers, and maintaining the total amount of liquid in the chambers substantially constant.

5. 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, supplying feed water to the unit in consonance with steam outflow rate, and maintaining total amount of liquid in the unit substantially constant.

6. The method of claim 5 including the step of regulating rate of vapor generation through transferring liquid from one chamber to the other whereby the extent of electrode immersion is varied.

7. The method of claim 5 including the step of regulating the conductivity of electrode pool water through controllably bleeding water therefrom.

8. 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 establishing a control effect representative of the amount of liquid in the two chambers, continuously establishing a control effect representative of the instantaneous relation between vapor outflow rate and liquid feed rate, and utilizing the two control effects conjointly to control the rate of supply of liquid feed to the unit.

9. The method of claim 8 wherein each of the control effects is a fluid pressure.

10. The method of claim 8 including the further step of continuously establishing a control effect representative of the specific conductivity of the pool water and utilizing this latter control effect in controllably bleeding water from the pool.

11. The method of claim 8 including the step of continuously establishing a control effect representative of vapor outflow pressure and utilizing this last control effect in transferring liquid from one chamber to another.

12. The method of claim 8 including the steps of continuously establishing a control effect representative of vapor pressure, continuously es-

establishing a control effect representative of vapor outflow rate, and conjointly interrelating such last two effects in transferring liquid from one chamber to another.

13. 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 providing water storage, which includes, continuously controlling the extent of electrode immersion and thereby the rate of steam generation by transferring liquid between the chambers, determining an electric demand factor, and utilizing the demand factor as a guide in regulating the rate and direction of transfer.

14. The method of claim 13 including the step of limiting the effect of the demand factor when vapor outflow pressure reaches a predetermined value.

15. The method of claim 13 including the step of limiting the effect of the demand factor when the extent of electrode immersion reaches a predetermined value.

16. The method of claim 13 including the step of limiting transfer of water from the pool chamber to the storage chamber when either minimum immersion of the electrodes in the pool chamber is reached or maximum predetermined vapor pressure is reached.

17. The method of claim 13 including the step of supplying feed water to the unit in consonance with steam outflow rate.

18. 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 providing water storage, which includes, continuously controlling the extent of electrode immersion and thereby the rate of steam generation by transferring liquid between the chambers, determining an electric demand factor, utilizing the demand factor as a guide in regulating the rate and direction of transfer, and maintaining the total amount of liquid in the unit substantially constant.

19. 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 providing water storage, which includes, continuously controlling the extent of electrode immersion and thereby the rate of steam generation by transferring liquid between the chambers, determining an electric demand factor, utilizing the demand factor as a guide in regulating the rate and direction of transfer, supplying feed water to the unit in consonance with steam outflow rate, and maintaining the total amount of liquid in the unit substantially constant.

20. The method of claim 13 including the step of regulating the conductivity of electrode pool water through controllably bleeding water therefrom.

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 providing water storage, which includes, continuously determining an electric demand factor, vapor outflow pressure, and electrode immersion; and conjointly

utilizing the determinations in continuously regulating the transferring of liquid from one chamber to the other.

22. In combination with an electric steam generator of the type having two interconnected pressure chambers in one of which electric current is dissipated in a water pool for vaporizing the water and the other providing water storage, means sensitive to the total amount of liquid in the two chambers, means sensitive to the rate of steam outflow, means sensitive to the rate of feed water inflow, comparison means conjointly acted upon by the second and third means, and control means responsive to the first means and the comparison means adapted to regulate the feed water supplying provisions.

23. The combination of claim 22 including conductivity determining means of the water in the unit and control means adapted to bleed water from the water pool under the domination of said conductivity determining means.

24. The combination of claim 22 including means sensitive to vapor pressure, and control means responsive to said pressure sensitive means adapted to regulate transfer of water between chambers.

25. The combination of claim 22 including means sensitive to vapor outflow rate, and control means responsive to said rate means adapted to regulate transfer of water between chambers.

26. The combination of claim 22 including means sensitive to vapor pressure, means sensitive to vapor outflow rate, and control means conjointly responsive to said pressure sensitive means and to said flow sensitive means adapted to regulate transfer of water between chambers.

27. The combination with an electric steam generator of the type having two interconnected pressure chambers in one of which electric current is dissipated in a water pool for vaporizing the water and the other providing water storage, means establishing a control effect continuously representative of the total amount of water in the two chambers, means establishing a control effect continuously representative of the rate of steam outflow, means establishing a control effect continuously representative of the rate of feed water inflow, comparison means continually comparing said steam outflow effect and said water inflow effect and establishing a control effect representative of the relation between steam outflow rate and water inflow rate, and control means responsive to said amount effect and said comparison effect adapted to regulate feed water supply rate.

28. The combination of claim 27 wherein said control effects are fluid pressures.

29. The combination of claim 28 including means establishing a fluid pressure control effect continuously representative of the specific conductivity of the pool water, and control means responsive to said conductivity representative effect arranged to regulate a bleed of fluid from the pool.

30. The combination of claim 27 including means establishing a control effect continuously representative of vapor pressure, and control means responsive to said pressure representative effect adapted to regulate transfer of water between chambers.

31. The combination of claim 27 including means establishing a control effect continuously representative of vapor pressure, means es-

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establishing a control effect continuously representative of vapor outflow rate, and control means conjointly responsive to said last two control effects and adapted to regulate transfer of water between chambers.

32. The combination with an electric steam generator of the type having two interconnected pressure chambers in one of which electric current is dissipated in a water pool for vaporizing the water and the other providing water storage, a water passage connecting the lower portions of the chambers, a steam passage connecting the steam space of the chambers, a throttling valve in the steam passage, a steam outflow pipe connecting to the steam space of the storage chamber, means sensitive to a variable condition of the unit operation adapted to control said valve resulting in a control of electrode immersion by transfer of water from one chamber to another, and means maintaining the total amount of liquid in the two chambers substantially constant.

33. The combination with an electric steam generator of the type having two interconnected pressure chambers in one of which electric current is dissipated in a water pool for vaporizing the water and the other providing water storage, a water passage connecting the lower portions of the chambers, a steam passage connecting the steam space of the chambers, a throttling valve in the steam passage, a steam outflow pipe connecting to the steam space of the storage chamber, and means sensitive to an electric demand factor adapted to control said valve resulting in a control of electrode immersion by transfer of water from one chamber to another.

34. The combination of claim 33 including means sensitive to vapor outflow pressure, and

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control means responsive to said last named means arranged to limit the effect of the electric demand factor when the vapor outflow pressure reaches a predetermined value.

35. The combination of claim 33 including means sensitive to extent of electrode immersion, and control means responsive to said last named means arranged to limit the effect of the electric demand factor when the extent of the electrode immersion reaches a predetermined value.

36. The combination of claim 33 including means sensitive to vapor outflow pressure, means sensitive to extent of electrode immersion, and control means responsive to both said last named means arranged to limit the effect of the electric demand factor when either a minimum electrode immersion or a maximum vapor pressure is reached.

37. The combination of claim 33 including means sensitive to steam outflow rate, and feed water supply control means positioned by said steam outflow sensitive means.

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