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APPARATUS FOR REGULATING ELECTRIC STEAM GENERATORS

Filed April 25, 1930

3 Sheets-Sheet 1

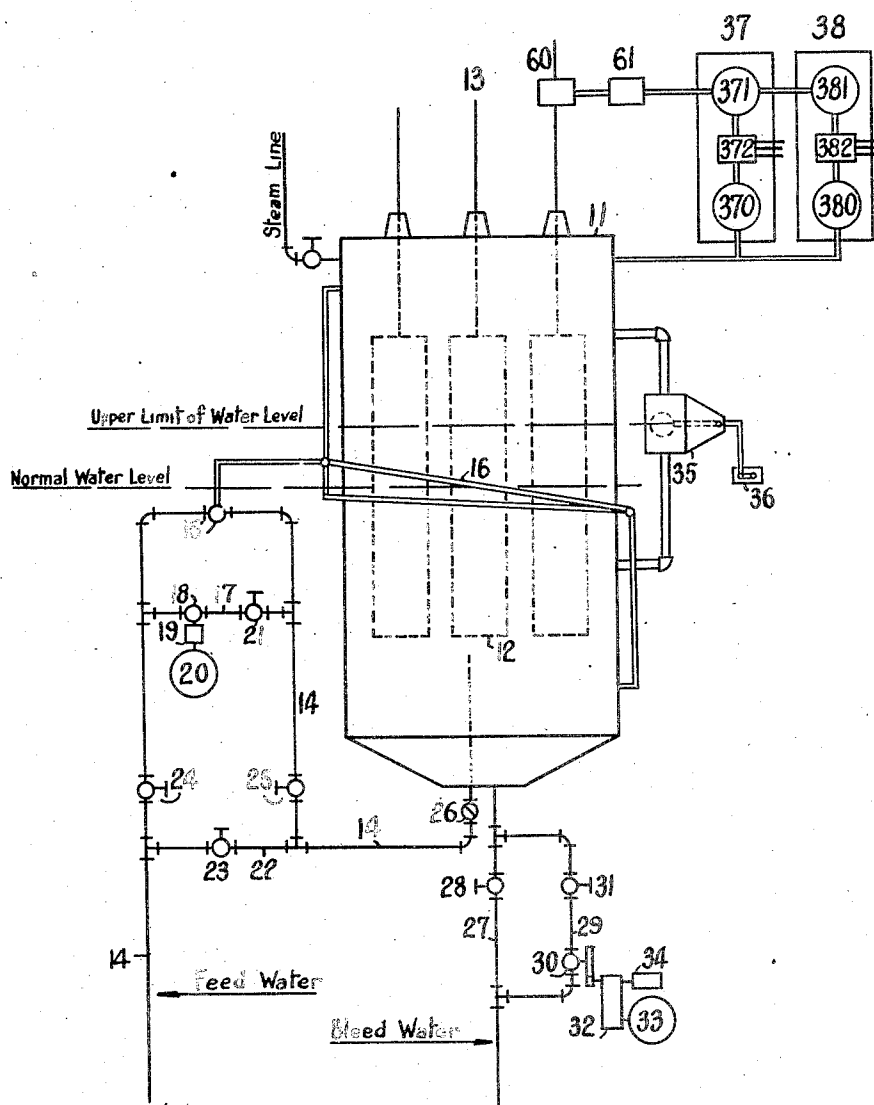


FIG. 1.

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3 Sheets-Sheet 2

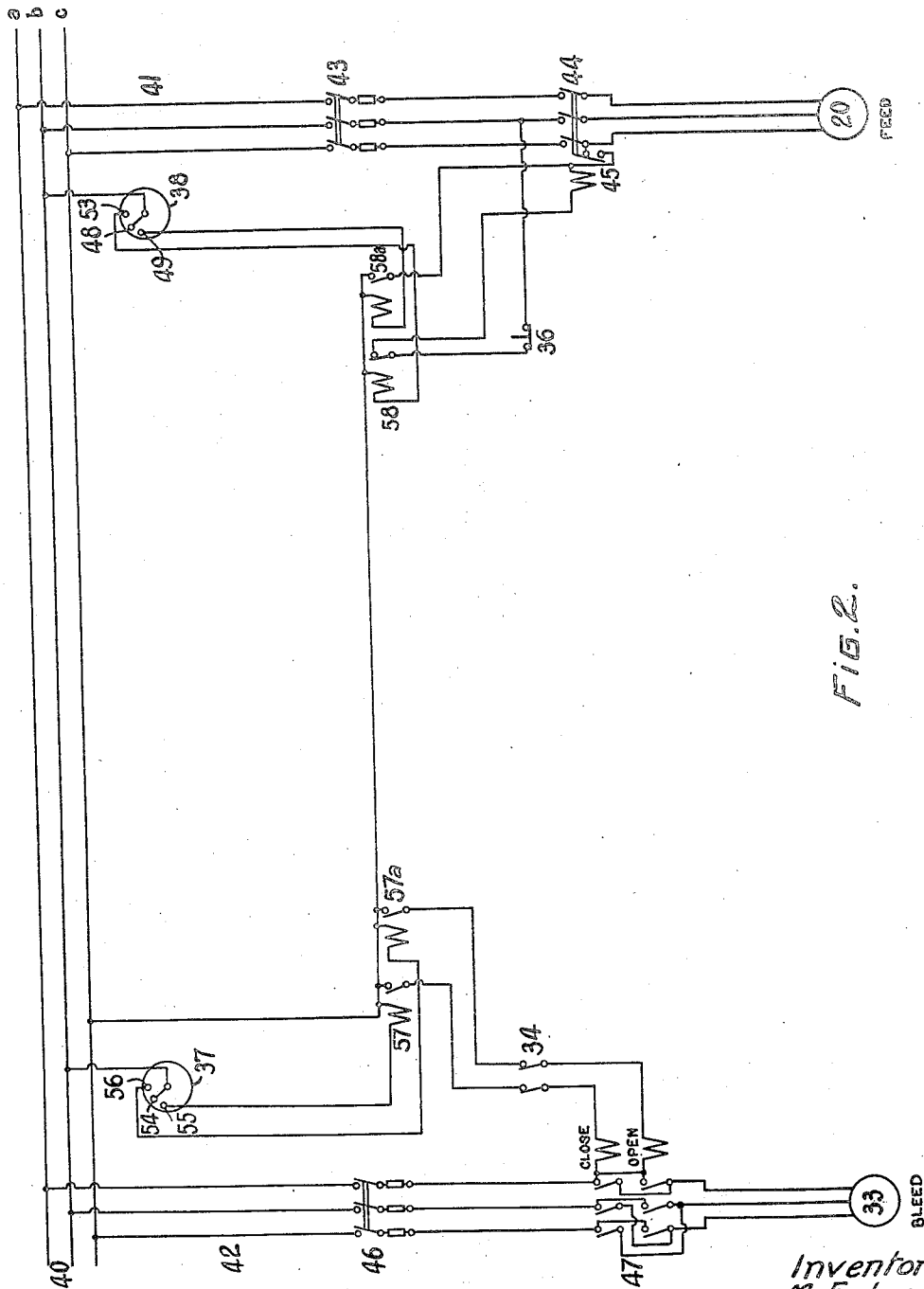


FIG. 2.

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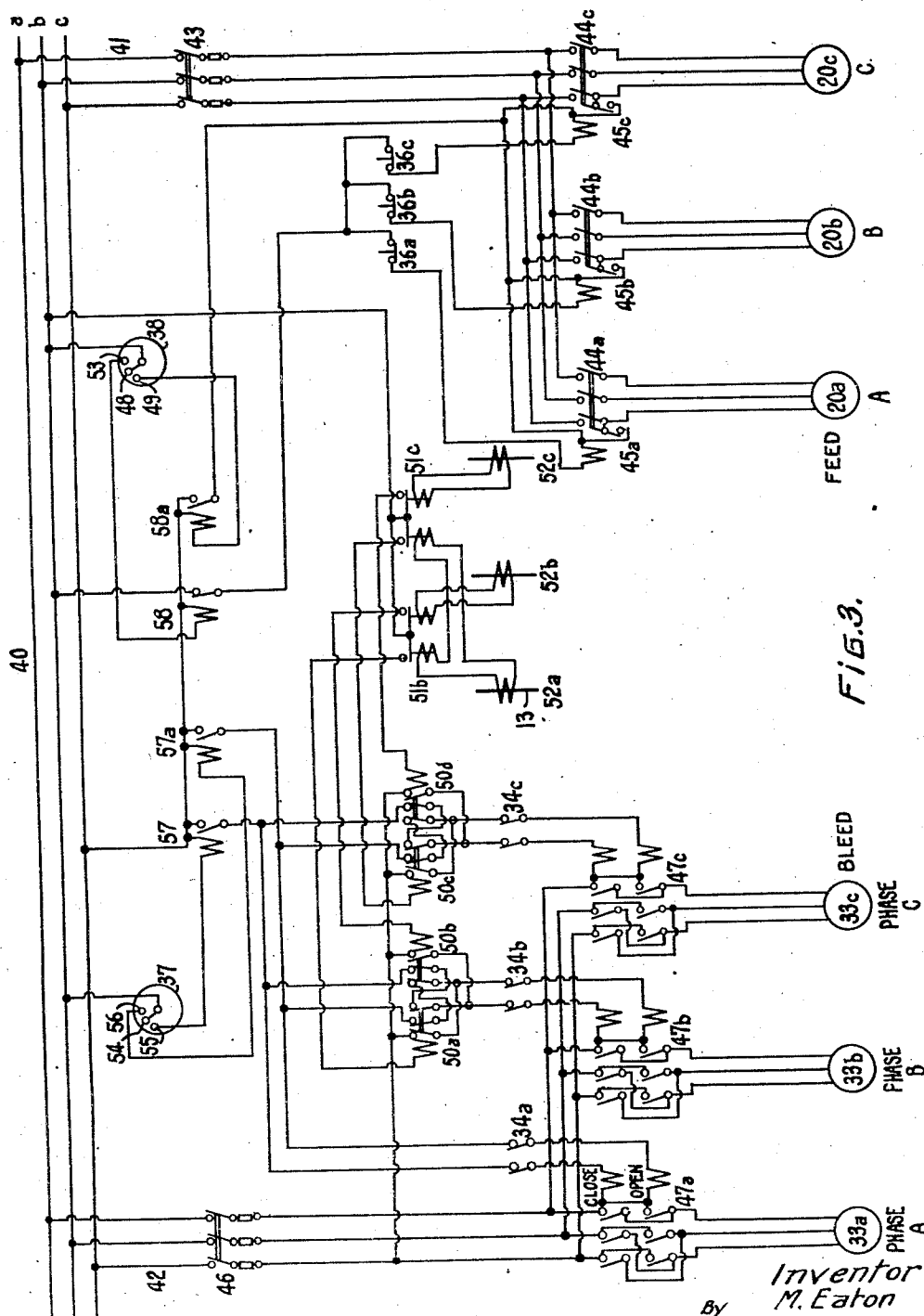
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3 Sheets-Sheet 3



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APPARATUS FOR REGULATING ELECTRIC STEAM GENERATORS

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This invention relates broadly to improvements in electric steam generators herein-after referred to, for brevity, as "electric boilers" or merely "boilers".

For the purposes of this invention, electric boilers are to be considered as divided into two classes, namely; those used for heating buildings and like purposes, usually operated on low voltage, with low steam pressure and in a closed system, so that the boiler feed water is entirely or almost entirely condensate and the current input being controlled entirely by altering the immersion of the electrodes; and those used in the industries to deliver steam for process steam heating, usually operated at high voltage and with high steam pressure and supplied continuously with water, which may be entirely raw water or partly raw water and partly condensate. The present invention has to do with boilers of the latter class and the primary objects of the invention are to eliminate manual control and to provide a system of automatic regulation which will either ensure delivery of steam normally at a constant adjustable rate and pressure or, alternatively, will ensure an approximately constant adjustable power input, and which will adjust the boiler conditions to increases or decreases of steam demand so as to maintain, in the first case, the pressure with as little variation as possible in the current input, and in the second case, the current input with as little variation as possible in the steam pressure.

Electric boilers of the type herein considered are usually used in connection with fuel fired boilers. When the electric boiler supplies the major part of the steam demand, it is preferable to operate the boiler at constant adjustable pressure but, when the electric boiler supplies only a minor part of the steam demand, it is preferable to operate it at constant adjustable power input and take care of pressure variations with the coal fired boilers. In many instances, it is desirable to operate a plant sometimes in one of the above ways and sometimes in the other way, for example, when changing from summer to winter conditions or when adjusting

the plant to variations in activity. Also, it is sometimes desired to operate two similar electric boilers in parallel and in such cases it is desirable to balance the power taken by the boilers.

Automatic regulation of electric boilers of the class referred to presents a number of difficulties. Assuming the applied voltage and spacing of the electrode to be constant, the power input varies according to three factors, namely, the immersion of the electrodes, the amount of impurities in the water and the temperature of the water. The amount of current taken increases as the submerged area of electrodes increases, also the conductivity of the water increases as the amount of impurities or the temperature increases. Ideally, the boiler operates at substantially constant water level, i. e., substantially constant electrode immersion, variations in steam demand being met by variations in power input effected by varying the amount of impurities in the water or the temperature of the water or both. The amount of impurity in the water is varied by bleeding off water from the boiler at a varying rate and by varying the feed of fresh water. This also varies the temperature. Merely regulating the immersion of the electrodes according to a varying steam demand is not practicable, since it leads to excessively high or low water levels, the former making it impossible to meet further sudden demand and the latter causing excessive current density which is very destructive.

Within the ordinary range of fluctuations, if the bleeding off stopped and the water level raised, the current input and steam output will increase. If comparatively cool feed water is admitted too rapidly, there will be a temporary drop in current input and steam output but, if the water level is lowered by bleeding off, there will be a decrease in current input and steam output. At any constant immersion of electrodes, the current input will decrease if the bleed off and feed are equally increased. This is due to an increase in resistance caused by reduction of impurities in the water and reduction of temperature resulting from the increased

amount of comparatively cool feed water. Conversely, if the bleed off and feed are decreased in such a way that the same electrode immersion is maintained, the amount of impurities in the water and its temperature will increase, giving rise to increased current input and steam output. The foregoing is more readily understood when it is remembered that an electric boiler of the type herein referred to operated at rated capacity evaporates every hour about ten times the volume of water normally contained in it at any instant. Thus, if the boiler is started with fresh water and none is bled off, in six minutes the amount of impurities is doubled. If the regulation is not properly effected, the results may be entirely different from the foregoing, for example, a too rapid increase in water level may cause such decrease in saturation (with impurities) and temperature that the current input and consequently the steam output will fall instead of rise and, conversely, a decrease of water level may cause such increase in saturation and temperature that the current input will rise instead of falling. For satisfactory results all three factors require variation by one another and, in addition, in a boiler where each phase is connected to a separate shell, the conditions in the separate shells require individual regulation. Because of the number of variables, manual regulation has been the rule but is not satisfactory.

According to the present invention, an electrically operating regulating system is provided responsive first to variations in steam pressure (or variations in amperage when operating to maintain constant power input) and secondly to variations in current input to separately regulate the feed and the bleeding off of water, the said system being on occasion responsive also to water level in the boiler. By means of this arrangement the conductivity of the water, both as to saturation and temperature, is controlled and the immersion of the electrodes may be varied within limits, the conductivity being regulated individually in the individual shells (if any) of the boiler to avoid as far as possible unbalancing of the phases.

In the accompanying drawings which illustrate one embodiment of the invention, to all the details of which the invention is not confined as modifications may be made and substitutions effected;—

Fig. 1 is a diagram illustrating the arrangement of the mechanical apparatus connected with a boiler which is shown as containing three electrodes connected to the three phases of the power supply. In boilers where each electrode is contained in a separate shell the mechanical arrangement is the same for each shell.

Fig. 2 is a wiring diagram showing the connection of the electrical apparatus for

controlling a three phase boiler having all three electrodes in one shell.

Fig. 3 is a wiring diagram showing the connection of the electrical apparatus for controlling a three phase boiler having a separate shell for each electrode.

Referring more particularly to the drawings, 11 designates a boiler shell containing one or three electrodes 12 according to the type of boiler, each connected to one phase of a three phase electric power circuit 13. The boiler is supplied with water from a feed water line 14 through a main regulating valve 15 controlled by any suitable sort of automatic mechanical regulating device, such as a Copes feed water regulator, indicated at 16 and adapted to maintain the water level in the boiler under ordinary conditions approximately at the normal level indicated. Two by-passes are provided in this water line; the first, designated 17, being located to by-pass the regulating valve 15 and including a self-closing auxiliary feed regulating valve 18, operated through suitable gearing 19 by a torque motor 20, and a cut-off valve 21 between the valve 18 and the boiler. The second by-pass, designated 22, is located to by-pass both the main regulating valve 15 and the first by-pass 17 and includes a manual regulating valve 23. Cut-off valves 24 and 25 are provided in the feed water line between the two by-passes and at opposite ends thereof. An inwardly opening check valve 26 is provided in the feed line between the previously mentioned elements and the boiler.

A bleed water line 27 leads from the bottom of the boiler and includes a manual regulating valve 28 and a by-pass 29 located to by-pass the valve 28 and including a regulating valve 30 and a cut-off valve 31 located between the regulating valve 30 and the boiler. The valve 30 is operated through a reducing gear 32 by means of a motor 33. A geared limit switch 34 is connected to the reducing gear 32. The reducing gear is such as to give a very large speed reduction, for example, with a motor 33 designed to operate at 1200 R. P. M. a gear ratio of 2400:1, which gives a speed of one-half R. P. M. on the valve spindle, has been found satisfactory, and substantially avoids hunting. The speed reduction effected by the gearing 19 is of a much lower order than is effected by the gearing 32, so that the valve 18 will be fully opened practically instantly after the motor is energized. A solenoid operated valve may be substituted for the motor operated valve 18.

Any suitable sort of feed water governor, such as a Locke float chamber, designated 35, is connected to the boiler and arranged to operate a cut-out switch 36 if the water in the boiler should rise to a predetermined maximum level. The limit switch 34 operates to

cut out the motor 33 and the switch 36 operates to cut out the motor 20, as will be hereinafter explained and may be seen in the wiring diagrams, Figures 2 and 3.

5 Governing instruments 37 and 38 are provided including adjustable "high" and "low" contacts and circuit makers movable in response to variations in the operating conditions of the boiler, or any equivalents of the
10 contacts and circuit makers which will produce the same effects. Essentially, these instruments control the motors 33 and 20 respectively, as will be hereinafter more fully explained. Preferably, each instrument includes two separately operable parts and a
15 selective device by means of which either part may be used. One part of each instrument is operable by variations in steam pressure in the boiler and the other part is operable by variations in power input. Specially
20 devised instruments may be used but entirely satisfactory results are obtained by coupling an electric contact making pressure control gauge, such as a Bourdon electric control gauge, or equivalent, through a double
25 throw switch with a contact making ammeter or equivalent. The pressure responsive part of each instrument is appropriately connected to the boiler and the electrically responsive part is connected through a current
30 transformer 60 to one of the power leads entering the boiler. In Figure 1, the dual function of the instruments has been graphically illustrated and shows pressure responsive parts 370 and 380; electrically responsive
35 parts 371 and 381; and double throw switches 372 and 382 connected between the parts so that either may be used. Each of the parts shown is provided with two adjustable contacts and movable circuit maker. In
40 the diagrams Figures 2 and 3 this duplication and the double throw switch have been omitted for simplicity and each instrument shown as having only two contacts and one
45 circuit maker representing that part of the instrument considered as being in use.

In the case of the pressure responsive parts 370 and 380 of the instruments 37 and 38, the contacts of one instrument are set for
50 normal pressure and low pressure and the contacts of the other instrument are set for normal pressure and high pressure. Obviously, these parts may be combined in a single device having three contacts. The contacts of the electrically responsive instrument parts 371 and 381 are normally set in
55 the same relation to the power input as the contacts of the pressure responsive parts are to the steam pressure and, as in the case of the parts 370 and 380, the parts 371 and 381 may be combined in a single device having
60 three contacts. The parts 371 and 381 are connected in series with one another and with the transformer and an adjustable rheostat 61 is connected in parallel between the

transformer 66 and the parts 371 and 381, all as shown in Figure 2. The ratio of the transformer determines the limits of adjustable load. The amount of current passing
65 through the parts 371 and 381 may be varied by altering the adjustment of the by-pass rheostat 61. In this way, the power input required to balance the parts 371 and 381 is made adjustable.

The foregoing description refers equally to
70 a single shell boiler as shown in Figure 1 and to a three shell boiler having a single electrode in each of the three shells, the equipment of each shell being as already described. While a single water feed arrangement and a
75 single bleed-off arrangement might serve for all three shells, it is preferred to provide each shell with a separate feed and a separate bleed-off regulator in order to take care of physical change in the shells and to prevent the current taken by each becoming unbalanced.

Referring now to the electrical regulating system shown in diagram in Figures 2 and 3, and referring particularly to Figure 2, 40 designates a three phase control power line from which power flows through lines 41 and 42
80 to the feed regulating motors 20 and the bleed regulating motors 33 respectively. In the diagram, Figure 3, the motors pertaining to the three shells are distinguished by the letters *a*, *b* and *c* corresponding to the phases A, B and C. The line 41 includes a fused
85 disconnecting switch 43 and a non-reversing magnetic switch 44 with under voltage attachment 45. The line 42 includes a fused disconnecting switch 46 and a reversing magnetic switch 47.

The circuit maker 48 of the instrument 38 is connected to one phase of the control circuit, designated B, and the low pressure contact 49 is connected to one side of the actuating solenoid of the normally open magnetic pilot switch 58^a, the other side of which solenoid is connected to another phase C of the control circuit. The high pressure contact 53 of instrument 38 is connected to one side of the actuating solenoid of the normally closed magnetic interrupting switch 58, the other side of which solenoid is also connected
105 to the phase C of the control circuit. One side of magnetic switch 58^a is connected to phase C of the control circuit and the other side is connected to the actuating solenoid of magnetic switch 44. This solenoid is then
110 connected in series with the magnetic switch 58 and the switch 36 to phase B of the control circuit. The undervoltage attachment 45 of switch 44 is connected to by-pass the magnetic switch 58^a.

The circuit maker 54 of the instrument 37 is connected to one phase B of the control circuit 40. The low pressure contact 55 is connected with the actuating solenoid of the magnetic pilot switch 57. The high pressure
125 130

contact 56 is connected to the actuating solenoid of the magnetic pilot switch 57^a. The other sides of the solenoids of magnetic switches 57 and 57^a are connected to phase C of the control circuit.

One side of magnetic switch 57 is connected to phase C of the control circuit 40 and the other side is connected in series with the limit switch 34 and the "closing" solenoid of the magnetic switch 47 to phase A of the control circuit. One side of the magnetic switch 57^a is also connected to phase C of the control circuit and the other side is connected in series with the limit switch 34 and the "opening" solenoid of magnetic switch 47 to phase A of the control circuit.

Referring to the diagram Figure 3, which is peculiar to the three shell boiler, it will be seen that the arrangement for controlling the motors 33^a, 33^b and 33^c is exactly as already described with the addition of two differential relay switches 51^b and 51^c, pertaining to phases B and C of the boiler respectively, each having one coil thereof in series with the current transformer 52^a pertaining to phase A, and having their remaining coils in closed circuit with transformers 52^b and 52^c on the power leads of phases B and C respectively. These relay switches or current balance relays control four magnetic supervising switches 50^a, 50^b, 50^c and 50^d, connected to the opening and closing solenoids of the reversing switches 47^b and 47^c. These magnetic switches each have three pairs of contacts mechanically interlocked, two pairs of which are normally closed and one pair normally open. One pair of normally closed contacts is connected in series with the "closing" solenoid of the reversing switch of the phase with which it pertains; the other pair of normally closed contacts is connected in series with the "opening" solenoid of the reversing switch. One side of each pair of normally open contacts is connected with one phase of the control circuit; the other side is connected to one or other of the solenoids actuating the reversing switch.

Magnetic switches 44^a, 44^b, and 44^c are connected in parallel and their actuating solenoids are connected in parallel on one side to magnetic switch 58^a. The other sides are also connected in parallel but before joining they pass through the water level controlled limit switches 36^a, 36^b and 36^c respectively. It will also be seen that for each of the motors 33^a, 33^b and 33^c there is a separate reversing switch (47^a, 47^b and 47^c respectively) and a separate limit switch (34^a, 34^b and 34^c respectively), these switches being connected in parallel with the control line 40. In order to relieve the contacts of the instrument 37 of the greater current taken by the three reversing switches, it is desirable to insert the opening and closing pilot switches 57, 57^a respectively between the instrument

and the opening and closing solenoids of the reversing switches to connect the reversing switch solenoids directly to the mains 40. When the instrument makes contact as already described, one of the pilot switches, for example, the "opening" switch 57^a, is closed and current flows from the mains through this switch and through the opening windings of the three reversing switches back to the mains.

Before considering operation of the control system, it is necessary to have in mind the operation of the boiler itself. For all constant steam demands the water level is the same and different demands also slight variations in any demand being met by varying the conductivity of the water and therefore the power input and steam output. Normally there is a continuous substantially constant bleeding off of "dirty" water, i. e., water more or less saturated with salts in solution or suspended matter which increase the conductivity of the water. Also, there is normally a continuous substantially constant feed of fresh clean water in amount sufficient to equal the bleed and the steam. If the bleed is reduced, less impurities are removed and the conductivity increases. Maintenance of constant level in the face of reduced bleed causes reduced feed, so that the proportion of cold incoming water to hot water in the boiler drops and the temperature rises, thus also increasing conductivity. Increased conductivity causes increased power input and consequent increased steam generation. From the foregoing it will be seen how different steam demands or gradual variations of any demand may be met without altering the water level.

If the bleed off is too slow for any given demand, the water level must be lowered to compensate for rise in conductivity and, if the bleed off is too fast, the water level must be raised to increase the current input. If the water level is either too high or too low, there is no opportunity for further increase or decrease of level to meet sudden changes in demand and, moreover, if the level is too low excessive current densities result and cause rapid deterioration of the electrodes.

If sudden changes occur in any steam demand, these cannot be compensated for in reasonable time by changing the conductivity of the water and it is necessary to temporarily change the level. This may be effected by greatly increasing the feed without reducing the bleed off but is not the best practice as it reduces saturation and temperature, thereby reducing the conductivity and partially nullifying the effect of increased water level, so that the level must be carried needlessly high. The best practice is to reduce the bleed off and increase the feed. In this way, the saturation and temperature of the water may be maintained for the higher

level and a rapid increase in power input effected, but it must be borne in mind that even with reduced bleed a too rapid increase of level will result in lowered temperature partially offsetting the increased immersion.

If the steam demand drops suddenly, the bleed off is increased and the feed increased. To merely decrease the feed will not serve, since the saturation and temperature of the water will increase and possibly result in a greater power input than obtained at the higher level.

To maintain an exactly constant water level would require simultaneous and opposite regulation of both bleed and feed but in practice small temporary variations of water level are not objectionable and enable the bleed and feed to be regulated sequentially. To meet any variation in steam demand it happens, fortunately, that change in bleeding to change conductivity and temperature produces change in water level in the same direction as would effect the desired regulation by varying the immersion of the electrodes, and that this change in water level is also in the direction necessary to operate an automatic feed water regulator to effect the desired change in feed. From these circumstances follows the desirability and practice according to this invention of first regulating the bleed to produce a temporary change in water level, which to some extent directly regulates the current input and also actuates the feed regulator to subsequently regulate the feed as desired. When using a regulator such as the Copes feed water regulator, this desired effect can be increased by increasing the slope of the thermostatic tube.

The operation is as follows;—

The contacts of the pressure responsive portion 370 of the governing instrument 37 are set so that the difference between them is not more than 5% of the desired operating pressure of the boiler, for example 2½% above and below the operating pressure, and the low contact of the pressure responsive portion 380 of the instrument 38 is set at, say 15% below operating pressure and the high contact at approximately the same setting as the low contact of the instrument 37. The contacts of the electrically responsive parts 371 and 381 of the instruments are set similarly to the contacts of the pressure responsive parts but with reference to a predetermined power input. The limit switch 34 is adjusted so that the bleed valve 30 will close only enough to permit a sufficiently rapid pick up of load and will not open more than is necessary to drop load at a rate sufficient for satisfactory operation. These settings differ for each installation and are ascertained experimentally. They may also be readjusted when required to meet physical changes in the boiler, such as formation of scale, etc. If, under conditions of steady or

slowly changing load, the valve hunts between the limits fixed by the limit switch, the valve is opening and closing too fast. If, under the same operating conditions, the pressure varies over 10%, the valve movement is too slow.

The boiler, having been filled with water to normal level and the power applied, is put in operation by hand. Valves 24, 25 and 31 are closed and control obtained by manipulating 23 and 28 in the manner usual for hand control. When the operating steam pressure is attained, the disconnecting switches 43 and 46 are closed to apply control voltage to the system and at the same time the valves 23 and 28 are closed and the valves 24, 25 and 31 opened to establish automatic control.

When operating to maintain constant pressure, the electrically responsive parts of the instruments 37 and 38 are disconnected from the control system by means of the switches 372 and 382 and the pressure responsive parts 370 and 380 connected. Similarly, when operating to maintain constant power input the pressure responsive parts 370 and 380 are disconnected and the electrically responsive parts 371 and 381 connected.

When operating under conditions of steady or slowly changing steam demand to maintain constant pressure, the feed water regulator 16 will hold the water level approximately constant, unless the control valve 18 is opened. If steam pressure falls sufficiently for the circuit maker 54 of instrument 37 to engage the low pressure contact 55, the solenoid of magnetic switch 57 is energized causing it to close. The closing of the switch energizes the "closing" solenoid of reversing switch 47. This switch will then close the circuit of motor 33 for rotation in such a direction that the bleed valve 30 will slowly close. Reduction in the bleed off increases the conductivity of water in the boiler by increasing the saturation and temperature of the water, so that the power input increases and causes more rapid generation of steam with consequent increase of pressure. As soon as the pressure rise carries the circuit maker away from the low contact 55, the switch 47 opens and breaks the circuit of motor 33, so that the valve 30 rests at the new setting. Unless there is a change in steam demand, the pressure will rise slowly now until the circuit maker 54 of the instrument 37 engages the high pressure contact 56. When this occurs the solenoid of the magnetic switch 57^a is energized, causing it to close. The closing of this switch energizes the "opening" winding of reversing switch 47, causing it to close in the reverse direction. Motor 33 will now rotate in the reverse direction slowly opening the bleed valve. When the bleed valve is opened, the increased bleed off of water reduces the saturation and temperature and so reduces the conductivity,

with the result that less power is taken by the boiler and the pressure falls slowly until the circuit maker of the instrument 37 leaves the high contact 56 and breaks the circuit of switches 57^a and 47. Switch 47 then opens and breaks the circuit of motor 33, so that the bleed valve stops.

In either the opening or closing of the bleed valve 30, the geared limit switch 34, which is included in the circuit between the instrument 37 and reversing switch 47, will be operated simultaneously with the bleed valve and will open the switch operating circuit when the prearranged limit of valve movement has been reached, if the pressure does not respond to the bleed valve adjustment rapidly enough to cause the actuating instrument to open the circuit sooner. Obviously, the limit switch affects the two circuits between the governing instrument and the reversing switch only one at a time, so that when it opens one circuit the other circuit is left intact for reverse operation of the valve. As soon as the reverse operation commences, the limit switch closes in the idle circuit. In addition to providing means for adjusting the limits of valve opening and closing, so that the movement may not be excessive if the pressure does not respond quickly, and thus preventing hunting, the limit switch also prevents the valve being jammed either open or shut and thus enables easy starting.

As formerly stated, the feed regulator 16 maintains an approximately constant water level in the boiler and by the means just described the boiler is regulated to meet any gradual change in steam demand.

If the increase in steam demand is so sudden that the pressure continues to fall after the bleed valve has closed to its set limit and reaches the low pressure for which the low contact of the instrument 38 has been set, the auxiliary feed valve, or feed regulator by-pass valve, 18 is opened to increase the admission of water and the immersion of the electrodes. In this connection, it may be noted the valve 21 should be so adjusted that when the valve 18 opens the feed water is not admitted fast enough to produce a cooling effect sufficient to cause the current input to fall rather than rise. When the circuit maker 48 of the instrument 38 touches the low contact 49, current flows from the control circuit 40 through the solenoid of the magnetic switch 58^a, causing it to close. Current will then pass through this switch from one phase of the control circuit through the solenoid actuating the magnetic switch 44, through the normally closed magnetic switch 58, through the limit switch 36 to another phase of the control circuit. The switch 44 is thus closed and closes the circuit of the motor 20, which operates and opens the auxiliary feed, or regulator by-pass, valve 18. The motor remains

energized but stalled and holds the valve 18 open. When the switch 44 closes, it closes the undervoltage switch 45 and short circuits magnetic switch 58^a, so that the circuit of the operating solenoid of switch 44 is now completed through the line 41 back to the mains 40. This enables the switch 44 to be held closed when the rising steam pressure shifts the circuit maker 48 away from the low contact 49.

When pressure rises sufficiently, the circuit maker 48 of the instrument 38 engages the high contact 53 and the current flows from the mains 40 through the circuit maker 48 and contact 53 and through the winding of switch 58 and back to the mains. The switch 58 is thus operated to break the circuit through the solenoid of switch 44, which returns to open position and opens the switch 45. When the switch 44 is opened, the circuit to the torque motor 20 is broken and de-energizes the motor, thus allowing the valve 18 to close.

If the water level should rise to the predetermined upper limit before the pressure rise operates through the instrument 38 to break the operating circuit of the magnet switch 44, the float device 35 will operate the cut-out switch 36 to break the circuit. After the extreme condition has ceased, the switch 36 returns to closed position in readiness for re-establishment of the operating circuit of switch 44.

If there is a sudden decrease in steam demand, the pressure will rise and cause a full opening of the bleed valve, as already explained, and the feed regulator 16 will supply sufficient cool water to maintain the level. The resulting rapid lowering of conductivity of the water will lower the power input with equal rapidity.

The foregoing description of the operation applies equally to the single shell and triple shell types of boiler and to the regulating systems shown in Figures 2 and 3. There is, however, upon occasion, an additional feature involved in the operation of the type of boiler having a separate shell for each electrode. Since each electrode 12 is in a shell by itself and the three bodies of water are isolated, it is not uncommon for the conductivity of the water to become different in the different shells, thus producing an unbalancing of the phases. If, then, the regulation was the same for all shells, the phases would remain unbalanced and probably become still more unbalanced. The current from the current transformer 52^a pertaining to phase "A" passes through one winding of each current balance relay 51^b and 51^c pertaining to phases "B" and "C" respectively and current from the transformers 52^b and 52^c pertaining to phases "B" and "C" flows through the other windings of the respective current balance relays 51^b and 51^c. It follows that if

the current taken by phases "B" or "C" become unbalanced relative to phase "A", the condition is reflected in one or both of the relays 51^b and 51^c, and causes one or both of these relays to operate. For example, should the current taken by phase "B" become greater than that taken by phase "A", the contacts shown on the side of relay 51^b with which the current transformer 52^a is connected will close. This causes the magnetic switch 50^a to operate. One pair of its normally closed contacts will open to open the operating circuit of the magnetic switch 47^b, so as to prevent it closing in the direction causing motor 33^b to rotate in the direction necessary to close the bleed valve of the shell containing phase "B". The pair of normally open contacts will close, thus causing current to flow through the "opening" solenoid of the magnetic switch 47^b. The other pair of normally closed contacts opens to prevent this operation being reflected in the magnetic switches 47^a and 47^c. The bleed valve of phase "B" will open or remain open until the phase balance is restored when the relay 51^b and the magnetic switch 50^a return to normal position.

Similarly, if the current taken by phase "B" becomes less than that taken by phase "A", the current balance relay 51^b will operate in such a way as to energize the magnetic switch 50^b, which in turn will cause the bleed valve of phase "B" to close or remain closed until the phase balance is restored. This supervising of phase balance is independent of pressure fluctuations. As long as the phases are balanced, the bleed valves open or close together, but as soon as an unbalance occurs it is immediately corrected. In this way, the regulation of the bleed in shells B and C is governed by the phase balance between the shells A-B and A-C and, therefore, since B and C are kept in balance with A, they are also kept in balance with each other. The magnetic switches 44^a, 44^b and 44^c controlling by-pass motors 20^a, 20^b and 20^c pertaining to phases "A", "B" and "C" respectively are operated in parallel, but should the water rise in the shell of one phase faster than in another, limit switches 36^a, 36^b and 36^c pertaining to phases "A", "B" and "C" are connected so that they can release their by-pass valves independently.

The advantages that may be realized by means of this invention are numerous and will be apparent to those skilled in the art, so that it suffices to state that using the herein disclosed system, an electric boiler may be operated practically without attention, except at starting or shutting down, and steam pressure and water level held between closer limits than are likely to be obtained by expert hand regulation. The pressure can be regulated at a point remote from the boiler, thus automatically compensating for changes

in pressure drop in the steam main due to varying rates of steam demand, which is of considerable advantage where close regulation of pressure is desired.

If it is desired that the automatic control should function to maintain constant adjustable power input to the boiler, the electrically responsive parts 371 and 381 of the instruments 37 and 38 are thrown into circuit and the pressure responsive parts 370 and 380 cut out of circuit. The operation is exactly as previously described, substituting terms of current input for terms of steam pressure.

The use of current balance relays 51^b and 51^c is essential to the successful control of a three shell boiler to maintain constant steam pressure but if pressure control is immaterial and the boiler is to be operated permanently under conditions of constant adjustable power input, the current balance relays and attendant switches 50^a, 50^b, 50^c and 50^d also the pressure responsive parts of the instruments 37 and 38 are not necessary and the electrically responsive parts of the instruments may be replaced by contact making ammeters (or equivalent) connected to each phase and to the remainder of the system to control the bleed off and feed to the three shells individually.

In the foregoing description, the term "magnetic switch" has been used in a generic sense and is to be understood as indicating any type of electrically operated switch suitable for the purpose. As formerly stated, motors are preferred for operating the feed and bleed valves but the invention is not confined to these and the term "motor" is to be understood as including any mechanism suitable for the purpose, such as solenoids or electrically controlled regulating valves of suitable engines for operating the feed and bleed valves.

Having thus described my invention, what I claim is;—

1. Means for regulating electric steam generators to maintain a selected condition of operation substantially constant including, in combination, an electric steam generator; a bleed valve therefor; and control apparatus arranged to open and close said bleed valve in response to variations in the generator steam pressure and generator current input.

2. Means for regulating electric steam generators to maintain a selected condition of operation substantially constant which includes the combination with the bleed valve of the generator, of a governing instrument responsive to variations in the selected condition, a motor operatively connected to said bleed valve, and a magnetic switch controlling the motor, said switch being connected to said instrument for control thereby.

3. Means for regulating electric steam

generators to maintain a selected condition of operation substantially constant, which includes the combination with the bleed valve of the generator, of a governing instrument responsive to variations in the selected condition, means controlled by said instrument and controlling the operation of said bleed valve, and a limit switch operatively connected with said valve and with said instrument controlled means and adapted to control the operation of said valve independently of said instrument.

4. Means for regulating electric steam generators to maintain a selected condition of operation substantially constant, which includes the combination with the bleed valve of the generator, of a governing instrument responsive to variations in the selected condition, a motor operatively connected to said bleed valve, a magnetic switch controlling the motor, said switch being connected to said instrument for control thereby, and a limit switch operatively connected with said valve and with said motor and adapted to control the motor independently of said instrument.

5. Means for regulating electric steam generators to maintain a selected condition of operation substantially constant, which includes the combination with the bleed valve and the main and auxiliary feed valves of the generator, of governing instruments responsive to variations in the selected condition, and means controlled by said instruments and controlling the operation of said bleed valve and auxiliary feed valve respectively.

6. Means for regulating electric steam generators to maintain a selected condition of operation substantially constant, which includes the combination with the bleed valve and the main and auxiliary feed valves of the generator, of governing instruments responsive to variations in the selected condition, motors operatively connected to said bleed valve and auxiliary feed valve respectively, magnetic switches controlling said motors, said switches being connected to said instruments for control thereby.

7. Means for regulating electric steam generators to maintain a selected condition of operation substantially constant, which includes the combination with the bleed valve and the main and auxiliary feed valves of the generator, of governing instruments responsive to variations in the selected condition, motors operatively connected to said bleed valve and auxiliary feed valve respectively, magnetic switches controlling said motors, said switches being connected to said instruments for control thereby, and a limit switch operatively connected with the bleed valve and connected in series between the controlling switch and the governing instrument pertaining to the bleed valve and adapted to

control the bleed valve motor independently of the associated governing instrument.

8. In combination with apparatus according to claim 1 a device arranged to selectively operate said bleed valve control apparatus in response to variations in the generator steam pressure or independently of the generator steam pressure and in response to variations in the generator current input.

9. A device according to claim 5, in which the instruments each include a part responsive to variations in generator steam pressure, and a part responsive to variations in current input to the generator, and a selective device whereby either part may be used.

10. A device according to claim 6, in which the operating motor of the bleed valve is reversible and the control switch thereof is a reversing switch and in which the auxiliary feed valve is self closing and adapted to be opened and held open when the operating motor thereof is energized.

11. A device according to claim 5, for the regulation of generators each comprising a plurality of shells, in which the electrodes connected to the several phases are located each in a separate shell, characterized in that each shell is provided with a separate bleed valve and separate associated control means therefor, all of said bleed valve control means being controlled by a single governing instrument, and in that each shell is provided with a separate auxiliary feed valve and separate associated control means therefor, all of said feed valve control means being controlled by a single governing instrument.

12. Means for regulating electric steam generators to maintain a selected condition of operation substantially constant which includes the combination with the bleed valve of the generator, of a governing instrument responsive to variations in the selected condition, a motor operatively connected to said bleed valve, a magnetic switch controlling the motor, said switch being connected to said instrument for control thereby, and a pair of magnetic pilot switches in series with the actuating windings respectively of said reversing switch, the actuating windings of said pilot switches being in series with said instrument in a shunt circuit from the circuits of the pilot switches and reversing switch.

13. A device for the regulation of generators each comprising a plurality of shells in which the electrodes connected to the several phases are located each in a separate shell to maintain a selected operating condition substantially constant, said device including for each shell a bleed valve, a reversing motor operatively connected to said bleed valve, a reversing switch controlling the motor, a magnetic pilot switch in series parallel with one actuating winding of each of said reversing switches, a second magnetic pilot

switch in series parallel with the other actuating winding of each of said reversing switches and a governing instrument, responsive to variations in the selected condition, in series with the actuating winding of each of said pilot switches and in a shunt circuit from the circuits including the pilot switches and reversing switches.

14. In combination with a device according to claim 13, magnetic supervising switches in series between the pilot switches and the operating windings of two of the reversing switches, and a pair of differential relay switches in series with the operating windings of said supervising switches, said relay switches being each operatively connected to the power leads of two shells of the generator for operation by unbalancing of the phases.

15. A device for the regulation of generators each comprising a plurality of shells in which the electrodes connected to the several phases are located each in a separate shell, to maintain a selected operating condition substantially constant, said device including for each shell a bleed valve, and a self closing auxiliary feed valve, a reversing motor operatively connected to the bleed valve, a reversing switch controlling the bleed valve motor, an opening motor operatively connected to the feed valve, a magnetic switch controlling the feed valve motor, a magnetic pilot switch in series parallel with one actuating winding of each reversing switch, a second magnetic pilot switch in series parallel with the other actuating winding of each of said reversing switches, and a governing instrument, responsive to variations in the selected condition, in series with the actuating winding of each of said pilot switches and in a shunt circuit from the circuits including the pilot switches and reversing switches, a magnetic pilot switch in series parallel with the operating windings of all said feed valve motor switches, a magnetic interrupting switch in series with said pilot switch and said feed valve motor switches, and a second actuating instrument responsive to variations in the selected condition in series with the actuating windings of said last mentioned pilot switch and said last mentioned interrupting switch.

16. Means for regulating electric steam generators to maintain a selected condition of operation substantially constant, which includes the combination with the main feed valve of the generator of an auxiliary feed valve, a governing instrument responsive to variations in the selected condition, and means controlled by said instrument and controlling the operation of said auxiliary feed valve.

17. Means for regulating electric steam generators to maintain a selected condition of operation substantially constant, which includes the combination with the main feed

valve of the generator of an auxiliary feed valve, a governing instrument responsive to variations in the selected condition, a motor operatively connected to said auxiliary feed valve to open same, a magnetic switch controlling the motor, said switch being connected to said instrument for control thereby.

18. In combination with a device according to claim 17, a magnetic pilot switch and a magnetic interrupting switch having the operating windings thereof separately connected to the governing instrument, said pilot switch and interrupting switch being in series with one another and with the operating winding of the motor controlling switch.

19. In combination with a device according to claim 17, a magnetic pilot switch and a magnetic interrupting switch having the operating windings thereof separately connected to the governing instrument, said pilot switch and interrupting switch being in series with one another and with the operating winding of the motor controlling switch, and an undervoltage switch mechanically connected to the motor controlling switch to be closed upon closing of said motor controlling switch and connected in series with the interrupting switch and the operating winding of the motor controlling switch and in parallel with the pilot switch thereby to maintain closed circuit through the operating winding of the motor control switch after opening of the pilot switch and until opening of the interrupting switch.

20. A device for the regulation of generators each comprising a plurality of shells in which the electrodes connected to the several phases are located each in a separate shell to maintain a selected operating condition substantially constant, said device including for each shell a self-closing auxiliary feed valve, a motor operatively connected to the valve, a magnetic control switch for the motor, in combination with a normally closed magnetic interrupting switch and a magnetic pilot switch in series with each other and in series parallel with the operating windings of all the motor control switches, and an actuating instrument responsive to variations in the selected condition in series with the operating windings of said interrupting and pilot switches.

21. In combination with a device according to claim 20, a water level actuated switch for each shell connected in series with the operating windings of the motor control switches.

22. Means for controlling electric steam generators to maintain a selected condition substantially constant which means includes a main feed valve, a water level actuated controlling means for said valve, an auxiliary feed valve, an operating motor for said auxiliary feed valve, a governing instrument responsive to variations in the selected condition, electrical means actuated by said instru-

ment to control said motor, and water level actuated means to render said electrical means inoperative.

23. Means for controlling electric steam generators to maintain a selected condition substantially constant which means includes a main feed valve, a water level actuated controlling means for said valve, an auxiliary feed valve, an operating motor for said auxiliary feed valve, a bleed valve, an operating motor for said bleed valve, governing instruments responsive to variations in the selected condition, electrical means actuated by said instruments to control said auxiliary feed valve motor and said bleed valve motor respectively, water level actuated means to render the electrical actuating means of the auxiliary feed valve inoperative and means operatively connected with the bleed valve to render the electrical actuating means of the bleed valve inoperative.

24. Means for controlling electric steam generators to maintain a selected condition substantially constant, which means includes for each shell of the generator a main feed valve, a water level actuated controlling means for said valve, an auxiliary feed valve, an operating motor for said auxiliary feed valve, and electrical controlling means for said motor in combination with a single governing instrument responsive to variations in the selected condition, connected to govern all said electrical controlling means, and a water level actuated means for each shell of the generator adapted to render the associated electrical controlling means inoperative.

25. Means for controlling electric steam generators to maintain a selected condition substantially constant, which means includes for each shell of the generator a main feed valve, a water level actuated controlling means for said valve, an auxiliary feed valve, an operating motor for said auxiliary feed valve, a bleed valve, an operating motor for said bleed valve, and individual electrical controlling means for said motors, in combination with a pair of governing instruments responsive to variations in the selected condition connected respectively to all the electrical feed control means and all the electrical bleed control means, a water level actuated means for each shell adapted to render the associated electrical feed control means inoperative, and separate means operatively connected with each bleed valve adapted to render the associated electrical bleed control means inoperative.

26. Means for regulating electric steam generators to maintain a selected condition of operation substantially constant, which includes the combination with a bleed valve and an auxiliary feed valve for the generator of motors operatively connected to said valves respectively and governing instruments for said motors respectively, said instruments be-

ing operatively connected to the generator and responsive to variations in the selected condition, the bleed valve governing instrument including adjustable contacts normally set slightly above and slightly below a point corresponding to the selected condition and a circuit maker movable by variations in said condition, and the feed valve governing instrument including adjustable contacts normally set slightly below and considerably below a point corresponding to the selected condition and a circuit maker movable by variations in said conditions, and means operative upon engagement of the circuit makers with said contacts to control said motors.

27. Means for regulating electric steam generators to maintain a selected condition of operation substantially constant, which includes the combination with a bleed valve and an auxiliary feed valve for the generator of motors operatively connected to said valves respectively and governing instruments for said motors respectively, said instruments being operatively connected to the generator and responsive to variations in the selected condition, the bleed valve governing instrument including adjustable contacts normally set slightly above and slightly below a point corresponding to the selected condition and a circuit maker movable by variations in said condition, and the feed valve governing instrument including adjustable contacts normally set slightly below and considerably below a point corresponding to the selected condition and a circuit maker movable by variations in said conditions, a pair of magnetic switches for each instrument having the operating windings thereof in series with the contacts respectively and the circuit maker, and means controlled by said magnetic switches for controlling said motors.

28. A device according to claim 27, in which each of the instruments includes a steam pressure responsive portion and a power input responsive portion, each of said portions having contacts and a circuit maker and a selective device adapted to connect and disconnect the said portions relatively to the windings of said magnetic switches.

29. In regulating means of the character described, the combination with an electric steam generator including a plurality of shells in which the electrodes connected to the several phases are located each in a separate shell, of a separate bleed valve for each said shell; separate control means for each said respective bleed valve; and a governing instrument responsive to variations in the condition of operation of the generator for controlling operation of said bleed valve control means.

30. Means for regulating electric steam generators to maintain a selected condition of operation substantially constant including, in combination, an electric steam gener-

ator; means for admitting feed water into said generator; and control apparatus arranged to control operation of said feed water admitting means in response to variations in the condition of operation of the said generator.

31. Means for regulating electric steam generators to maintain a selected condition of operation substantially constant including, in combination, an electric steam generator; means to control ingress and egress of water into and from said generator; and control apparatus arranged to control the operation of said water ingress and egress control means in response to variations in the condition of operation of said generator.

32. Means for regulating electric steam generators to maintain a selected condition of operation substantially constant including, in combination, an electric steam generator; means for admitting feed water into said generator; and control apparatus arranged to operate in response to variations in current input condition of the said generator, independently of the steam pressure, to control the operation of the said feed water admitting means.

33. Means for regulating electric steam generators to maintain a selected condition of operation substantially constant including, in combination, an electric steam generator; means for admitting feed water into the said generator; and control apparatus arranged to operate in response to variations in steam pressure, independently of the current input, to control the operation of the said feed water admitting means.

In witness whereof, I have hereunto set my hand.

MILTON EATON.