May 27, 1952 G. V. BERG ET AL 2,598,490

CONTROL OF THE STEAM GENERATION IN ELECTRIC STEAM BOILERS

Filed Aug. 6, 1947 2 SHEETS—SHEET 1

Fig. 1

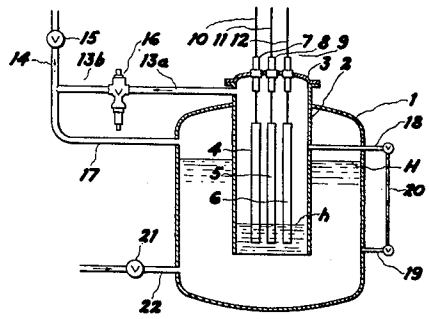
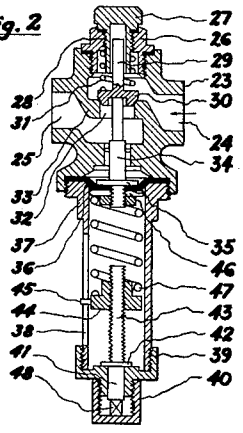


Fig. 2



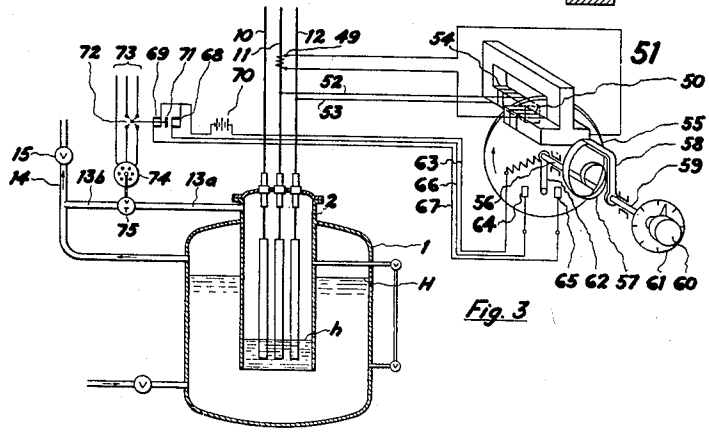


Fig. 3

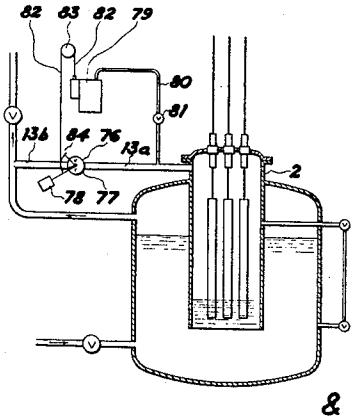


Fig. 4

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CONTROL OF THE STEAM GENERATION IN ELECTRIC STEAM BOILERS

Filed Aug. 6, 1947 2 SHEETS—SHEET 2

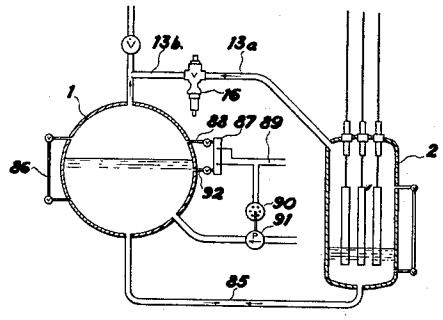

Fig. 5

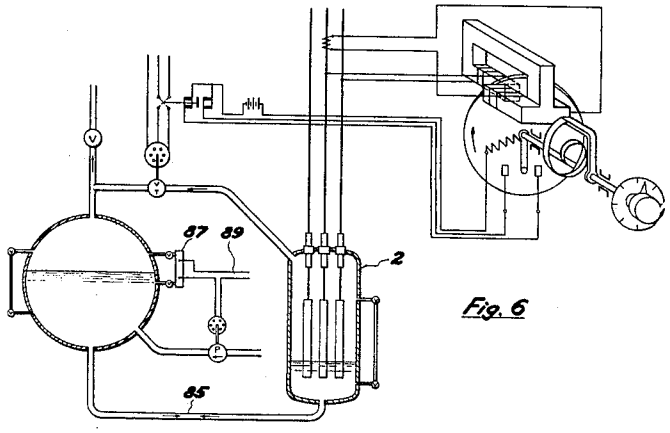

Fig. 6

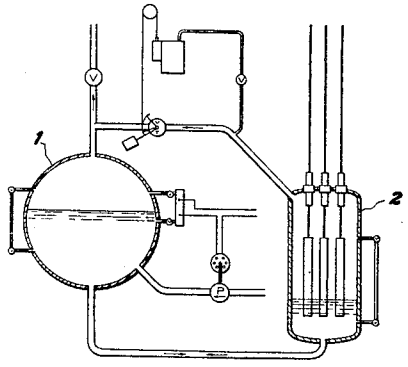

Fig. 7

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CONTROL OF THE STEAM GENERATION IN ELECTRIC STEAM BOILERS

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7 Claims. (Cl. 219—40)

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The present invention relates to the control and regulation of the generation and supply of steam from electric boilers, comprising a vessel including steam generating electrodes and a steam reservoir communicating therewith via a water passage. It has been previously proposed to regulate the steam pressure in such boilers or the quantity of steam produced or the electric power supplied by increasing or decreasing the surface of contact between the electrodes and the water. This change in the contact surface is produced by raising or lowering the water level. Slow variations of the water level may be obtained by increasing or decreasing the quantity of water which is fed into the boiler. Or, if a rapid lowering of the water level and a rapid reduction in power input corresponding thereto is desirable, it has been usual to open a blow-off valve in the bottom of the boiler and tap off some water until the desired lowering of the water level is obtained. The tapped-off water carries much heat which it is desirable to regain, for instance, by letting the tapped-off water pre-heat the feed-water intended to be supplied to the water space of the boiler. However, in many plants there is no possibility to utilize all the heat embodied in the tapped-off water in which case a certain loss of heat is unavoidable.

The present invention has for its object to establish a rapid regulation of the steam generation without any noticeable loss of energy and consists substantially therein that the supply steam generated in the electrode vessel is withdrawn via a steam exhaust communicating with the steam space of the reservoir, the flow resistance of which exhaust is controlled by a regulator, upon the steam generation exceeding a desired rate or upon a manual shifting, to increase the resistance of the steam exhaust so that an increased drop of pressure is caused between the steam spaces of the electrode vessel and of the reservoir and the water level in the vessel is lowered and the steam generation reduced, and that, upon the steam generation falling below a desired rate or a corresponding manual shifting, to reduce the flow resistance of the steam exhaust so that the liquid level in the vessel is allowed to rise and the steam generation increases. In one of its embodiments the invention has for its object to let the pressure of the boiler directly cause the intended change in the liquid level and for this purpose the regulator is provided with an impulse member adapted, upon the pressure in the boiler exceeding a certain value, to shift the regulator so as to increase the

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flow resistance and vice versa. This may be accomplished by making the impulse member depending on the pressure in the electrode vessel or in the reservoir.

In another embodiment the invention has for its object to hold the supplied electric power at a constant value which is of considerable economical importance, particularly at certain tariffs adopted by the power stations. For this purpose the regulator has an impulse member adapted, upon the electric power delivered to the electrodes exceeding a certain upper limit, to shift the regulator so as to increase the flow resistance of the exhaust or, upon the power falling below a certain lower limit, to shift the regulator to reduce the flow resistance.

The invention will be more closely described with reference to the accompanying drawings in which connection further features of the invention will be explained.

Fig. 1 on the drawing shows diagrammatically a vertical section through a boiler having an electrode vessel built in the reservoir according to an embodiment of the invention.

Fig. 2 is a vertical section through a regulator used in Fig. 1.

Figs. 3 and 4 illustrate modifications of the embodiment shown in Fig. 1.

Figs. 5 to 7 show three further embodiments which principally agree with those shown in Figs. 1, 3 and 4 respectively although they are applied in a boiler having two thermically separated vessels.

In the embodiment shown in Fig. 1 there is inserted inside an exterior vessel 1 forming the steam reservoir, an interior vessel 2 forming the electrode vessel, which is open at its bottom and closed at its top by means of a detachable lid 3 in which the electrodes 4, 5 and 6 are suspended in insulating bushings 7, 8 and 9. To the bushings are connected three times 10, 11 and 12 supplying three phase alternating current from an electric power source not shown. From the electrode vessel 2 a steam exhaust line 13a, 13b leads to a tap-off line 14 having a tapping valve 15. Between the line portions 13a and 13b there is included a pressure regulator 16 of a design more closely described below. The lines 14 and 13b communicate via a pipe line 17 with the upper portion of the steam space of the steam reservoir 1. A pipe 18 leading from the interior of the electrode vessel, and a pipe 19 communicating with the lower part of the reservoir extend to a water level indicator 20, on which the water level in the electrode vessel 2 may be read-off.

Feed-water is admitted through the feed-water tube 22 controlled by a valve 21.

The design of the regulator 16 may be seen from Fig. 2. In a block 23 there are provided an input port 24 and an output port 25, in which the line portions 13a and 13b are connected. Further, there is in the block 23 an upper bore into which a sleeve 26 is threaded and sealed. The upper aperture of the sleeve 26 is closed by a sealing capsule 27 provided with a guiding sleeve 28 and a valve stem 29 having a valve member 30 reciprocable in said sleeve. Between the valve member 30 and a shoulder in the sleeve 26 a compression spring 31 is held under tension. The valve member 30 cooperates with a valve seat provided in an aperture 32 in a partition 33 separating the inlet and outlet ports 24 and 25 respectively. Against that side of the valve member which is turned from the stem 29 a stem 34 bears which has a flange 35. On the side of the flange turned away from the valve 30 there is a membrane 36 which is made of rubber or other flexible material. The membrane 36 is at its periphery squeezed between, on the one hand, an off-set in the block 23 and, on the other, a sleeve 37 screwed into the block 23. The interior of said sleeve communicates with the surrounding atmosphere through a slot 38 provided therein. The lower end of the sleeve is provided with a screwed-on sleeve nut 39, at the lower part of which a capsule 40 is threaded-on. In the sleeve nut 39 there is slidable a stem 41 having a flange 42 which normally bears upon the upper side of the sleeve nut 39. The stem 41 is threaded at 43 and the nut 44 is threaded thereon and provided with a guide pin 45 slidable in the slot 38 whereby the nut 44 is displaceable axially but is prevented from rotating. Between a washer 46 secured to the stem 34 and bearing against the underside of the membrane 36, on the one hand, and an off-set shoulder on the nut 44, on the other, a compression spring 47 is inserted under a biasing tension. This tension may be regulated by actuating a portion 48 of the stem 41 which portion, for instance, may be square and rotating said stem so that the nut 44 is screwed upwards or downwards. The tension of the spring 47 should be so adjusted that the sum of said spring tension and the air pressure acting on the one side of the membrane 36 are at equilibrium with the tension of the spring 31 and the steam pressure in the port 25 acting on the opposite side of the membrane 36, approximately corresponding to the steam pressure prevailing in the reservoir 1 provided this pressure is at a certain predetermined limiting value. If the steam pressure exceeds this value the membrane 36 and the spring 47 will apparently admit the valve member 30 to approach its seat so as to take up a closed position as shown in Fig. 2. On the other hand, if the pressure falls below said value the valve body 30 is held raised from its seat by the action of the spring 47.

The apparatus operates as follows. It is assumed that the water level H in the reservoir 1 and the water level h in the electrode vessel 2 take up the positions shown in the figure and that the regulator 16 is open and lets through supply steam to the tap-off line 14. If now, for instance, the rate of withdrawal of steam is reduced by partially closing the valve 15 it occurs that the steam generation taking place in the electrode vessel 2 exceeds the consumption of steam wherefore the pressure is increased until the valve member 30 starts to throttle the passage through the regulator 16. Hereby a drop of pressure is caused between the exhaust line portions 13a and 13b so that the pressure prevailing in the electrode vessel 2 will be higher than that in the reservoir 1. Hereby water will be pressed out of the vessel 2 through its bottom opening and into the reservoir 1 whereby the water level h of the electrode vessel 2 is further lowered and the contact surface of the electrodes 4 to 6 as well as the steam generation therefrom is reduced. When finally the pressure has fallen sufficiently far or if the tapping-off of supply steam through the valve 15 increases the steam pressure in pipe 13b is reduced so far that the regulator 16 again increases the free passage therethrough whereby the pressure drop between the pipe portions 13a and 13b is again reduced and the water level h in the electrode vessel 2 again rises so that the contact surface increases and the steam generation grows.

As seen from the drawing the area of the water surface at the level h in the electrode vessel 2 is considerably less than the area of the water surface at the level H in the reservoir 1. Hereby even comparatively great fluctuations in the level h cause but small fluctuations in the level H. For this purpose the walls of the vessels 1 and 2 should be so shaped that said proportion between the areas of the water surfaces is valid at least within the range for normal fluctuations of the levels h and H.

In the above embodiment the pressure in the reservoir 1 has been decisive for the operation of the regulator 16. According to Fig. 3 the supplied electric power and thus the evaporation pro unit of time are decisive for the course of the regulation. For this purpose a current transformer 49 is included in the supply conductor 11 which transformer is associated with a current coil 50 in a power relay 51. One of the phase-voltages is conducted via the conductors 52 and 53 to the voltage coil 54 of the relay. The current and voltage coils actuate a rotatable metal disk 55 according to Ferrari's well known principle often applied in wattmeters. The disk 55 is mounted on a rotatable shaft 56 which is elastically coupled via a helical spring 57 with an arm 58 carried by a rotatable adjusting spindle 59. In turn this is controlled by a knob 60 the angular position of which is indicated on a scale 61. The shaft 56 is provided with a contact arm 62 which is connected via a flexible conductor and a stationary conductor 63 to a battery 70 and which cooperates with two contacts 64, 65 associated with conductors 66 and 67. The one terminals of two relay coils 68, 69 are associated with said conductors, whereas their opposite terminals are connected in parallel to the battery 70. According as the arm 62 touches the contact 64 or the contact 65 the conductor 66 and coil 68 or the conductor 67 and coil 69 respectively are energized from the battery 70. The relay coils 68 and 69 control an armature 71 adapted to actuate a phase reversing switch 72 included in two of the phases of the supply conductors 73 of a three phase induction motor 74. Depending thereon whether the armature 71 is attracted by the coil 68 or the coil 69 the switch 72 will shift the phase sequence in the stator of the motor 74 so that its rotor is rotated in the one or in the other direction. The rotor of the motor 74 is coupled to a throttle valve 75 preferably via a worm gear or other gearing having a large gearing-down ratio, which, however, is not indicated on the

drawing. The throttle valve 75 is included between the pipe portions 13a and 13b in similar manner as the regulator 16 in Fig. 1. The stem of the valve 75 is in known manner provided with a throttle disk which throttles the free passage through the valve in different degrees depending on different angular positions of the stem.

The arrangement according to Fig. 3 operates as follows. It is assumed that the electric power supplied through the conductors 10 to 12 has a given value and corresponds to the withdrawal of a certain quantity of steam through the tap-off pipe 14 and the valve 15. At this state of equilibrium the levels *h* and H have the positions shown on the drawing. It is further assumed that the knob 60 then is so set in relation to the scale 61 that the turning moment exerted by the disk 55 is counter-balanced by the spring 57 so that the arm 62 plays in the inter-space between the contacts 64 and 65 without touching them whereby the relay coils 69 and 68 are idle and the armature 71 is held in such an intermediate position that the switch 72 holds the two phases controlled thereby disconnected so that the motor 74 stands still.

If now from any cause the level *h* is altered, for instance, raised the contact surface of the electrodes and the electric power supplied through the conductors 10 to 12 are immediately increased and the disk 55 is subjected to an increasing turning moment whereby the countertension of the spring 57 is overcome and the arm 62 makes contact with, for instance, the contact 64. Hereby the coil 68 is energized and the armature 71 brings the switch 72 to such a position that the motor 74 begins to rotate in a direction causing the throttle valve 75 to increase the drop of pressure between the lines 13a and 13b so that the pressure in the vessel 2 is increased and the level *h* is lowered. The conditions will be reversed if the level *h* should sink it being then instead the contact 65 which actuates the coil 69 via the conductor 67 whereby the motor 74 is started in the opposite direction and the throttle valve 75 is gradually opened so that the pressure drop between lines 13a and 13b is reduced and the level *h* rises.

In the embodiment shown in Fig. 4 the position of the regulator is controlled by the pressure in the electrode vessel 2 through the following arrangement. A throttle valve 76 is included between the line portions 13a and 13b and has a rotatable valve stem 77 normally held in a fully open position by a restoring force, such as a weight 78 or spring power. A regulator 79, by way of example, of the type disclosed by T. Källe in his United States Patents Nos. 1,738,072 and 2,147,977 has an impulse member which communicates, via a pipe line 80 and a valve 81 included therein, with and is controlled by the pressure in the line 13a which pressure is practically the same as the pressure in the electrode vessel 2. The regulator 79 is adapted, upon the pressure exceeding a certain value, to exert a pull in a wire 82 which actuates via a pulley 83 a sector 84 which is coupled to the stem 77 in such a manner that a pull in the wire 82 of sufficient strength urges the stem 77 to rotate against the action of the weight 78 so that the flow resistance through the valve 76 is gradually increased and a pressure drop is caused between the line portions 13a and 13b.

The arrangement according to Fig. 4 operates in similar manner as that described above in connection with Fig. 1 with the difference that it is the pressure in the electrode vessel 2 and not the pressure in the reservoir 1 which is decisive for the operation of the arrangement.

In the arrangement shown in Fig. 5 the reservoir 1 is thermically separated from the electrode vessel 2 if the exhaust pipes 13a and 13b and the water passage via a pipe 85 are disregarded. The steam exhaust is provided with a throttle valve controlled by a regulator 16. Said regulator may be of the design shown in Fig. 2. The reservoir 1 is preferably provided with a water level indicator 86 and also with an electric level control device 87 of known design adapted, upon the level exceeding the position corresponding to the pipe 88, to interrupt the supply line 89 to an electric motor 90 operating a feed pump 91 for injecting feed water into the vessel 1. The device 87 connects the motor again into circuit when the water has fallen again to the level corresponding to the pipe 92.

The arrangement shown in Fig. 5 operates in all essential aspects in the same manner as that shown in Fig. 1.

Also in the embodiment shown in Fig. 6 the electrode vessel 2 and the reservoir 1 are thermically separated. Otherwise said arrangement agrees with that shown in Fig. 3. Also its operation depending on the supplied electric power is the same as that described in connection with Fig. 3.

The embodiment according to Fig. 7 differs from the one shown in Fig. 4 only through the separate arrangement of the vessels 1 and 2. The operation agrees with that described in connection with Fig. 4.

In the above embodiments the regulator has been shifted automatically. However, it is within the scope of the invention to cause a change in the water level by resetting the regulator manually so as to shift its position of equilibrium.

With the term "water" used in this connection is understood any evaporable liquid suitable for operating the arrangement as described.

It is of course understood that the present invention is by no means limited to the specific showing in the drawings but also comprises any modifications within the scope of the appended claims.

What we claim is:

1. An electric vapor generator comprising a vessel containing a vapor generating electrode, a vapor reservoir, means containing automatically operating flow controlling means connecting the upper portions of said vessel and said reservoir, a steam take-off line connected to said reservoir, and means connecting the lower portions of said vessel and said reservoir, the vessel and the reservoir each being partially filled with the liquid to be vaporized, the levels of which in the vessel and reservoir are controlled by the relative pressures maintained above the liquid levels by the action of said flow controlling means, said electrode being partially submerged in the liquid in said vessel so that change of liquid level therein varies the electrode area in contact with said liquid to change the rate of vapor generation.

2. An electric vapor generator comprising a vessel containing a vapor generating electrode, a vapor reservoir, means containing automatically operating pressure regulating means connecting the upper portions of said vessel and said reservoir, a steam take-off line connected to said reservoir, and means connecting the

lower portions of said vessel and said reservoir, the vessel and the reservoir each being partially filled with the liquid to be vaporized, the levels of which in the vessel and reservoir are controlled by the relative pressures maintained above the liquid levels by the action of said pressure regulating means, said electrode being partially submerged in the liquid in said vessel so that change of liquid level therein varies the electrode area in contact with said liquid to change the rate of vapor generation.

3. An electric vapor generator comprising a vessel containing a vapor generating electrode, a vapor reservoir, means containing flow controlling means connecting the upper portions of said vessel and said reservoir, a steam take-off line connected to said reservoir, means connecting the lower portions of said vessel and said reservoir, and means responsive to the electric power supplied to said electrode for operating said flow controlling means, the vessel and the reservoir each being partially filled with the liquid to be vaporized, the levels of which in the vessel and reservoir are controlled by the relative pressures maintained above the liquid levels by the action of said flow controlling means, said electrode being partially submerged in the liquid in said vessel so that change of liquid level therein varies the electrode area in contact with said liquid to change the resistance to the flow of electric current through the liquid and the electrode.

4. An electric vapor generator comprising a vessel containing a vapor generating electrode, a vapor reservoir, means containing flow controlling means connecting the upper portions of said vessel and said reservoir, a steam take-off line connected to said reservoir, means connecting the lower portions of said vessel and said reservoir, and means responsive to the pressure in said vessel for operating said flow controlling means, the vessel and the reservoir each being partially filled with the liquid to be vaporized, the levels of which in the vessel and reservoir are controlled by the relative pressures maintained above the liquid levels by the action of said flow controlling means, said electrode being partially submerged in the liquid in said vessel so that change of liquid therein varies the electrode area in contact with said liquid to change the rate of vapor generation.

5. An electric vapor generator comprising a vessel containing a vapor generating electrode, a vapor reservoir, means containing pressure regulating means connecting the upper portions of said vessel and said reservoir, a steam take-off line connected to said reservoir, means connecting the lower portions of said vessel and said reservoir, and means responsive to the pressure in said reservoir for operating said pressure regulating means, the vessel and the reservoir each being partially filled with the liquid to be vaporized, the levels of which in the vessel and reservoir are controlled by the relative pressures maintained above the liquid levels by the action of said pressure regulating means, said electrode

being partially submerged in the liquid in said vessel so that change of liquid therein varies the electrode area in contact with said liquid to change the rate of vapor generation.

6. In an electric steam generator, a vaporizing chamber, an electrode extending downwardly thereinto for immersion in chamber-contained water to be vaporized, a storage chamber in water-interchange communication with said vaporizing chamber, a steam connection between the upper portions of said vaporizing and storage chambers and a main offtake for the generator steam in unobstructed communication with the storage chamber end of that connection, a throttling valve in said steam connection intermediate the two chambers, and control means for said valve responsive to the steam pressure in one of said two chambers and effective to vary the valve-introduced resistance to steam flow out of the vaporizing chamber in accordance with said pressure whereby to govern the vaporizing chamber water level and electrode immersion in a way which automatically keeps the rate of steam generation in the vaporizing chamber matched with the rate at which steam leaves the generator by way of said main offtake.

7. In an electric steam generator, a vaporizing chamber, an electrode extending downwardly thereinto for immersion in chamber-contained water to be vaporized, a storage chamber in water-interchange communication with said vaporizing chamber, a steam connection between the upper portions of said vaporizing and storage chambers and a main offtake for the generator steam in communication with the upper portion of the storage chamber, a throttling valve in said steam connection intermediate the two chambers, and control means for said valve responsive to the steam pressure in one of said two chambers and effective to vary the valve-introduced resistance to steam flow out of the vaporizing chamber in accordance with said pressure whereby to govern the vaporizing chamber water level and electrode immersion in a way which automatically keeps the rate of steam generation in the vaporizing chamber matched with the rate at which steam leaves the generator by way of said main offtake.

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