

Dec. 10, 1963

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3,114,028

ELECTRODE TYPE VAPOR GENERATOR

Filed Feb. 13, 1957

4 Sheets-Sheet 1

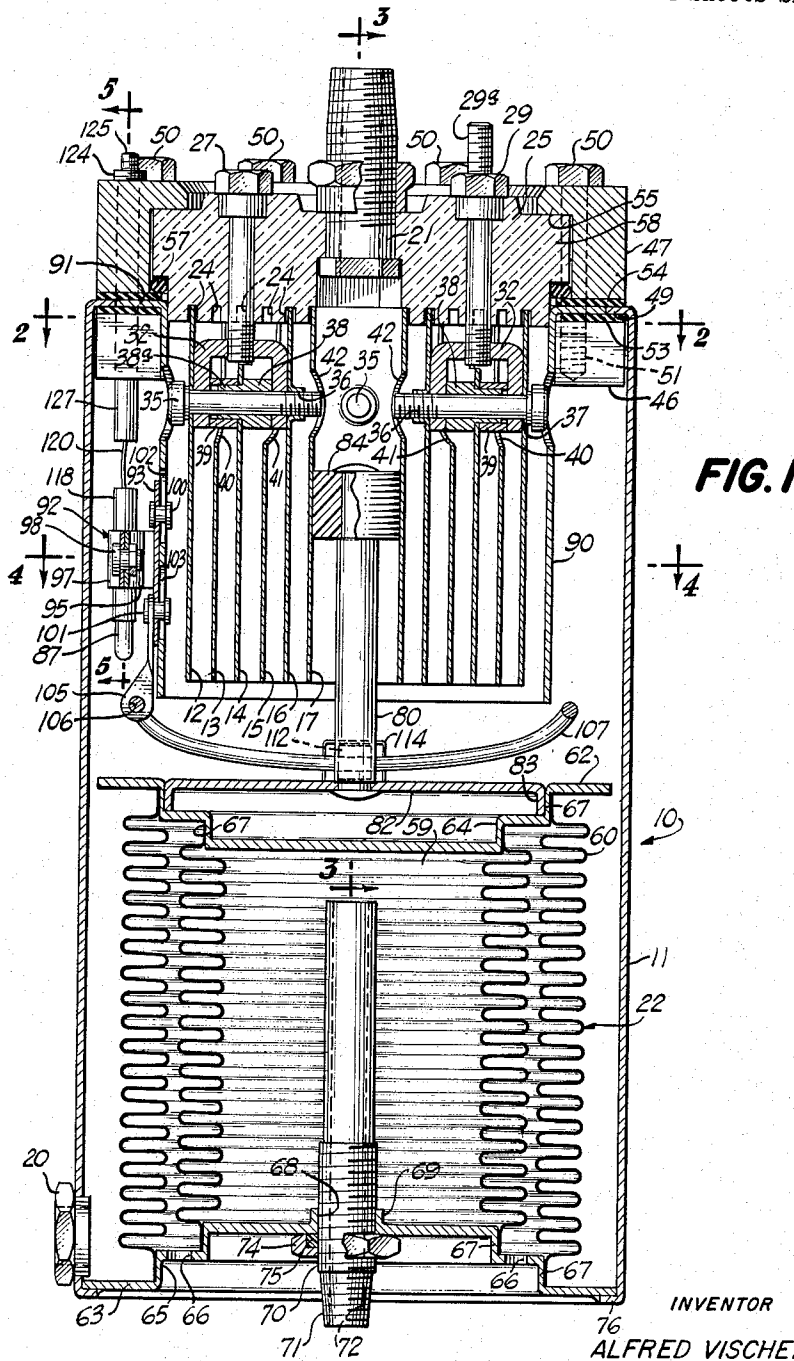


FIG. 1

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FIG. 2

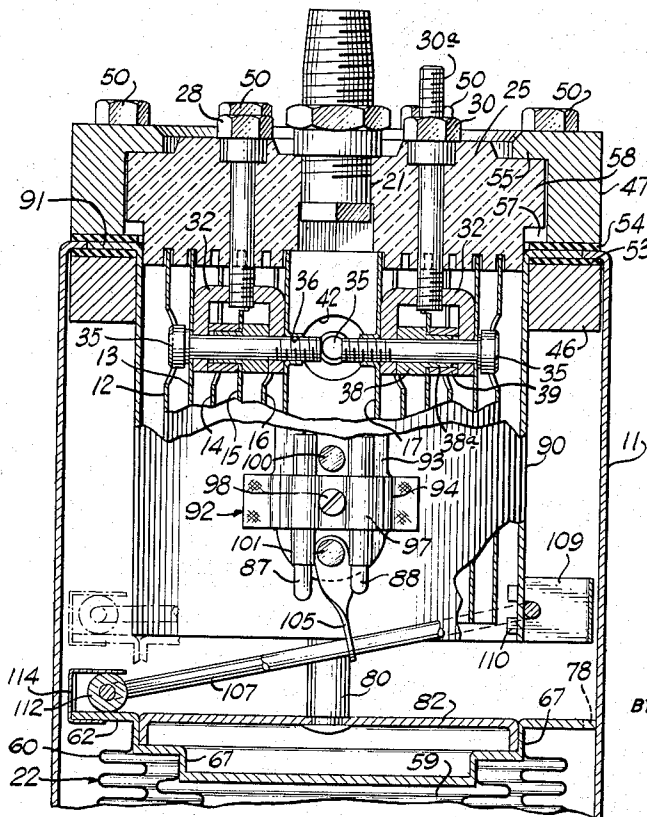
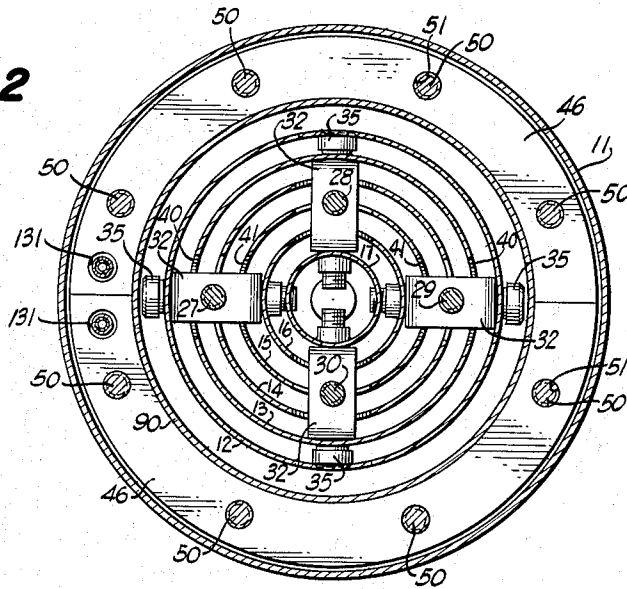


FIG. 3

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4 Sheets-Sheet 3

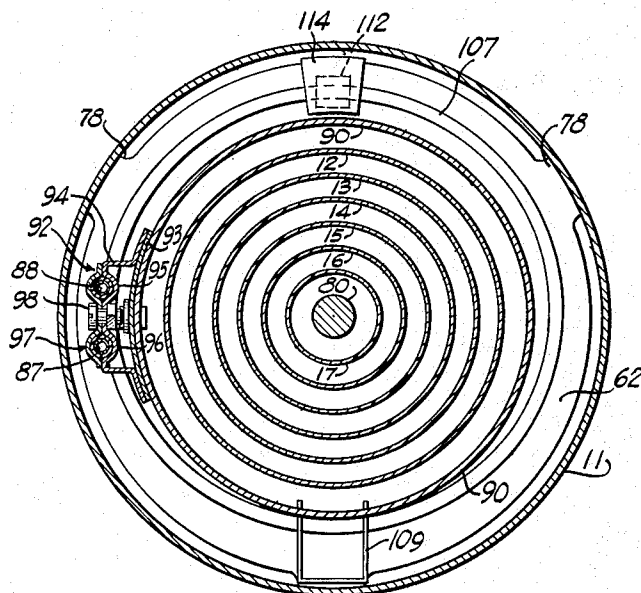


FIG. 4

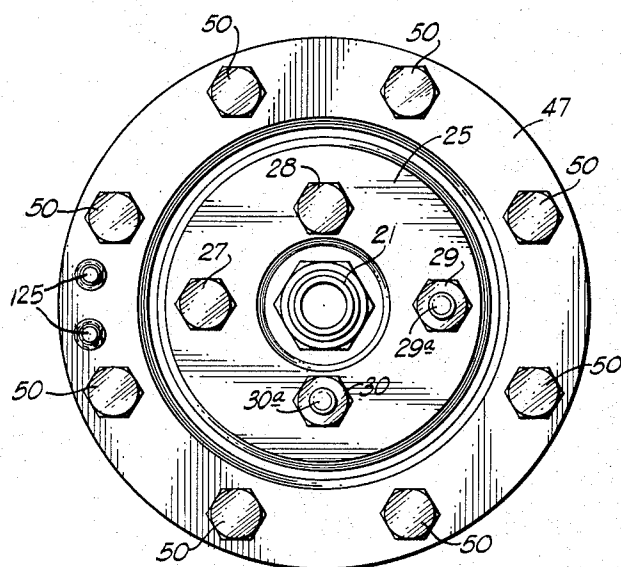
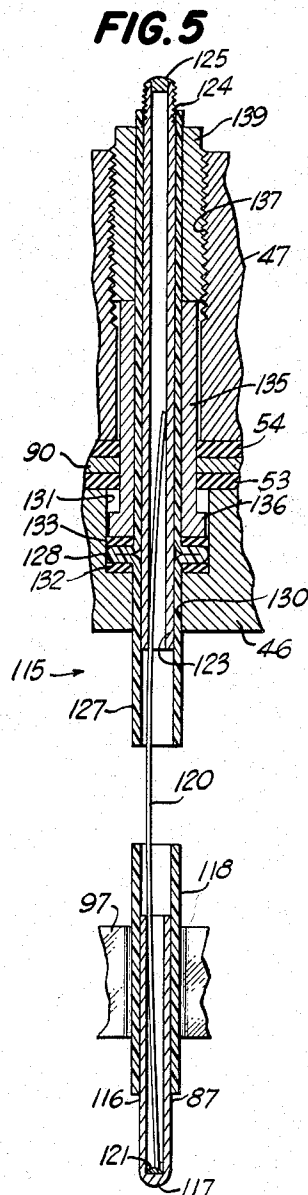


FIG. 6



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ELECTRODE TYPE VAPOR GENERATOR

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4 Sheets-Sheet 4

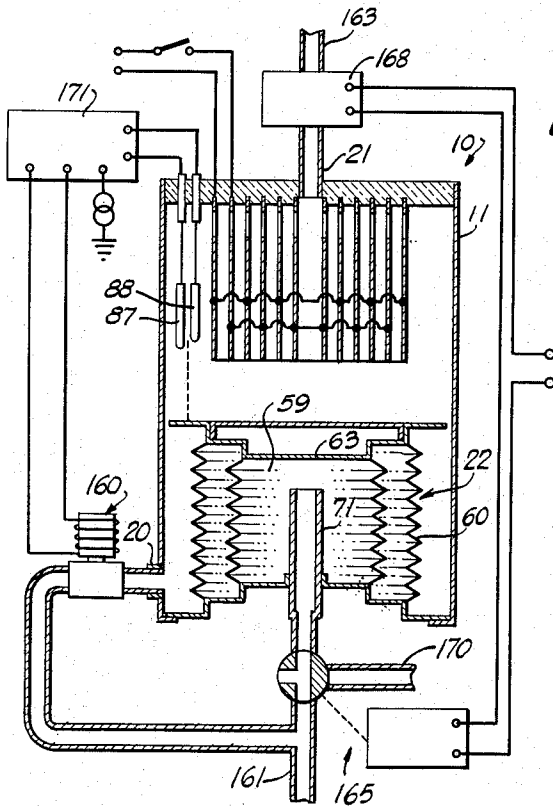


FIG. 7

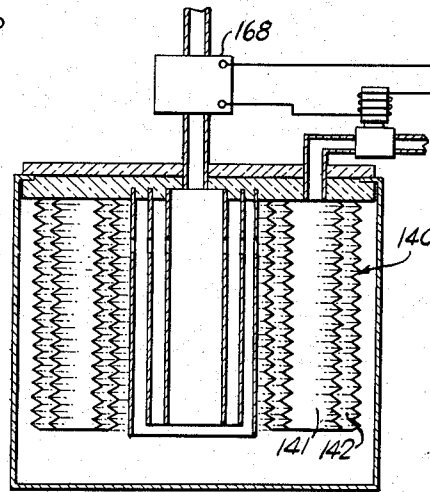
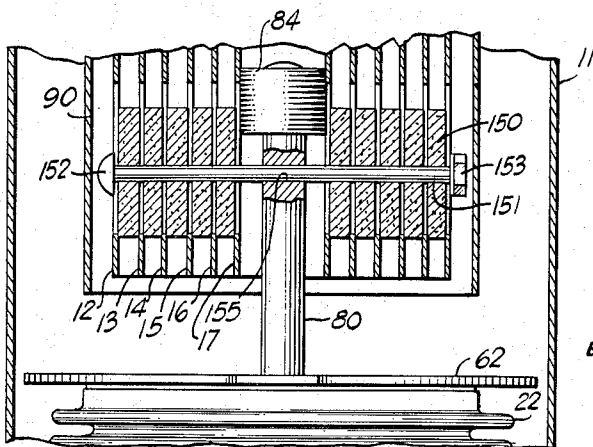


FIG. 8

FIG. 9



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3,114,028

ELECTRODE TYPE VAPOR GENERATOR

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Filed Feb. 13, 1957, Ser. No. 639,992
16 Claims. (Cl. 219—40)

The present invention relates to vapor generators and particularly to vapor generators of the type in which a plurality of electrodes are positioned in direct contact with the liquid to be vaporized so that the passage of current through the liquid may be used to heat and vaporize it.

A principal object of the present invention is to provide a new and improved vapor generator of the above described type which is small and compact in design and can generate relatively large quantities of vapor in short periods of time.

Another object of the present invention is to provide a new and improved vapor generator of the above type in which positive control of the quantity of liquid interconnecting the heating electrodes is achieved.

A further object of the present invention is to provide a new and improved vapor generator which is simple in construction, reliable in use, inexpensive to manufacture, and small in size in relation to the quantity of steam which it can generate.

Another object of this invention is to provide a new and improved vapor generator having means for controlling the quantity of vapor generated in accordance with the demand of the load connected thereto.

Briefly, the above and further objects are realized in accordance with the present invention by providing a vapor generator which includes a single steam generating chamber in which a plurality of electrodes are fixedly mounted and which includes displacement means within the chamber for controlling the amount of water interconnecting the electrodes in accordance with a predetermined condition.

The invention, both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the following specification taken in connection with the accompanying drawings, in which:

FIG. 1 is a partially sectioned side elevational view of a vapor generator embodying certain aspects of the present invention;

FIG. 2 is a cross-sectional view of the device of FIG. 1 taken along the line 2—2 thereof, assuming the entire structure to be shown in FIG. 1;

FIG. 3 is a cross-sectional view taken along the line 3—3 of FIG. 1, assuming the entire device to be shown therein;

FIG. 4 is a cross-sectional view taken along the line 4—4 of FIG. 1, assuming the entire structure to be shown therein;

FIG. 5 is an enlarged cross-sectional view taken along the line 5—5 of FIG. 1;

FIG. 6 is a top plan view of the device of FIG. 1, assuming the entire structure to be shown therein;

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FIG. 7 is a schematic diagram of a control circuit used in connection with the vapor generator of the present invention; and

FIGS. 8 and 9 are side elevational partly schematic views of two alternative embodiments of the present invention.

Referring now to the drawings and particularly to FIGS. 1—7 thereof, the present invention is there shown as embodied in a steam generator 10 comprising a tubular chamber defining member 11 which is sealed at its opposite ends and in which are disposed a plurality of concentrically arranged tubular electrodes 12, 13, 14, 15, 16 and 17. A source of voltage is connected between alternate ones of the electrodes 12—17 and the liquid to be vaporized which, in most cases is water, is supplied to the chamber through an input duct 20 so as to maintain a relatively constant quantity of liquid in the chamber irrespective of the quantity of liquid vaporized and passed out of the generator 10 through an output duct 21.

In order to adjust the level of water in the chamber and thus the quantity of vapor generated in accordance with the demands of the load to which the output duct 21 is connected, a displacement means 22 is disposed within the chamber and is expanded or contracted to control the level of liquid in the chamber so as to generate the quantity of steam desired. In this connection it might be noted that the quantity of liquid supplied to the chamber 20 is also controlled, but the supply of liquid is controlled only in accordance with the amount of liquid in the chamber and not in accordance with any characteristic of the output vapor of the generator. Therefore, it will be clear to those skilled in the art that the liquid is supplied to the chamber 11 through the duct 20 for the sole purpose of replacing that liquid which is vaporized and supplied to the load and not to control the contact area between the liquid and the electrodes 12—17.

Considering the operation of the generator 10 very briefly, when operation thereof is initiated, liquid is supplied through the duct 20 until a predetermined quantity thereof is provided in the chamber, at which time the supply of liquid is interrupted, preferably by automatic means. Since there is no vapor pressure in the chamber at this time, the displacement means 22 is fully expanded and the contact area between the electrodes 12—17 and the liquid is a maximum. If and when the electrodes are then energized from a source of energizing voltage across which they are connected, a maximum amount of steam is generated and delivered to the load. If, for some reason, the quantity of steam required by the load is reduced, such, for example, because the vapor in a pressure tank reaches a predetermined value, the displacement means 22 is contracted thereby to reduce the level of liquid in the chamber and thus to decrease the contact area between the liquid and the electrodes. Consequently, the quantity of steam generated is reduced to a lesser value or if desired the generation of vapor may be completely interrupted. In the meantime, the supply of liquid to the chamber through the duct 20 has been controlled so as to maintain a fixed quantity of liquid within the chamber. Obviously, since some of the liquid has been vaporized, this has been achieved by feeding additional liquid to the chamber. As indicated above, the generator 10 may

operate with the displacement means 22 contracted to its limiting position so that the level of the liquid is below the bottom of the electrodes 12-17, in which case no current passes through the liquid and no vapor is generated. If desired, however, the lowest level of liquid may be such that a small contact area is provided between the liquid and the electrodes 12-17 so as to cause the generation of enough steam to compensate for any losses in the system such as is due to condensation. When a demand for more vapor again occurs, the displacement means 22 is expanded to raise the level of liquid in the chamber and thus to increase the contact area between the liquid and the electrodes 12-17 which immediately supplies an increased quantity of vapor to the load.

Considering the steam generator 10 in greater detail, the electrodes 12-17 are respectively positioned in concentric grooves 24 in a substantially cylindrical cover member 25 which is constructed of a good insulating material such, for example, as ceramic. The electrodes 12-17 are secured to the cover 25 by means of a plurality of bolts 27, 28, 29 and 30 which extend through spaced apart apertures in the cover 25 and which are connected to certain ones of the electrodes 12-17. As is shown in FIG. 1, the electrodes 12, 14, and 16 are electrically interconnected and attached to the bolts 27 and 29 by means of two U-shaped brackets 32 through the arms of which respectively extend a plurality of bolts 35. The bights of the brackets 32 are provided with threaded apertures into which the lower end of the bolts 27 and 29 are threaded to press the electrodes 12, 14, and 16 firmly against the cover 25.

In order to rigidly secure the brackets 32 to the electrodes 12, 14 and 16, a pair of screws 35, one for each bracket 32, clamp the electrodes into a rigid unit. As shown, the electrode 16 is provided at diametrically opposed locations with necked-up apertures 36 into respective ones of which the screws 35 are threaded, the heads of the screws 35 bearing against the aperture defining portions 37 of the electrode 16. Pairs of inter-fitting sleeves 38 and 39 surround the screws 35 between the arms of the brackets 32, and the sleeves 38 each have a necked-down portion 38a which fit loosely in suitable apertures in the electrode 14 as well as in the sleeve 39. Consequently, when the screws 35 are tightly threaded into the apertures 36 the electrode 16 is clamped between the opposing faces of the sleeves 38 and 39 and the electrodes 12 and 16 are respectively clamped against the arms of the brackets 32. A good mechanical and electrical connection is thus achieved.

The other electrodes 13, 15 and 17 are attached to the cover 25 in the same manner as are the electrodes 12, 14 and 16. The bolts 29 and 30 are provided with upwardly extending threaded portions 29a and 30a, respectively, to facilitate connection of the electrodes across a source of energizing voltage. Also, and as best shown in FIGS. 1 and 3, the electrodes 13, 15 and 17 are provided with cut-outs 40, 41 and 42 in the vicinity of the studs 35 which interconnect the electrodes 12, 14 and 16. The electrodes 12, 14 and 16 are provided with similar cut-out portions in the vicinity of the studs 35 which interconnect the electrodes 13, 15 and 17. Consequently, the two groups of electrodes 12-17 are isolated from one another.

In order to provide a hermetically tight seal between the chamber defining tube 11 and the cover 25, a pair of metallic clamping rings are provided, the inner clamping ring being designated 46 and the outer clamping ring being designated 47. The tube 11 is provided at the top with an in-turned annular lip 49 against the opposite sides of which the rings 46 and 47 are clamped by means of a plurality of bolts 50 which extend through suitable apertures in the upper ring 47 and are threaded into threaded holes 51 in the upper side of the lower ring 46. In addition, inner and outer flat sealing gaskets

53 and 54 are provided between the respective adjoining faces of the rings 46 and 47 to effect a steam-tight seal.

In order to prevent the cap 25 from being blown up out of the chamber when the vapor pressure therein exceeds the ambient pressure, the ring 47 is provided with an annular reentrant flange 55 which overlies the peripheral portion of the top of the cap 25 and thus holds it in place within the generator 10. As shown in FIG. 1, an O-ring sealing gasket 57 is positioned between the gasket 54 and the head 58 of the cover 25.

The displacement means 22, which in the embodiment of the invention illustrated in FIG. 1 is positioned in the bottom of the chamber, comprises a pair of inner and outer bellows 59 and 60 which are spaced apart and the space between the bellows 59 and 60 is vented to the atmosphere so as to provide an annular dead air space between the bellows 59 and the liquid in the chamber. In this manner, the temperature of the fluid used to control the displacement of the means 22 does not affect the temperature of the liquid to be vaporized. The inner and outer bellows 59 and 60 are respectively connected and sealed as by seam welding to upper and lower circular end plates 62 and 63. As best shown in FIG. 1, the plates 62 and 63 are provided with intermediate step portions 64 and 65 to provide vertically disposed cylindrical shoulders 67 against which the end portions of the bellows 59 and 60 are welded. The shoulders 67 are concentric and, therefore, maintain the bellows 59 and 60 in spaced apart concentric relationship. The upper plate 62 is imperforate and the lower plate 63 in addition to the vents 66 which open into the space between the bellows 59 and 60 is provided with a central aperture 68 which is necked-up at 69 to threadedly receive the portion 70 of a tubular inlet and stop member 71. The member 71 has a central bore and is provided with a tapered lower threaded nipple section 72 for attachment to suitable plumbing such, for example, as a tap to a water main so that tap water may be fed through the tube 71 into the chamber of the inner bellows 59 to control the displacement thereof. It should be noted that the use of the two bellows 59 and 60 enables the use of a relatively small quantity of fluid for causing a large change in the effective volume of the displacement means 22.

Since the upper end of the tube 71 serves as a stop to limit the downward movement of the upper plate 62 and thus the compression of the displacement means 22, the threaded connection between the member 71 and the plate 63 permits external adjustment of the maximum limit of contraction of the displacement means 22. In order to facilitate adjustment of the position of this stop means from outside of the generator 10, a locking nut 74 having a resilient center section 75 is threaded onto the portion 70 of the member 71 and secures it at a fixed position with respect to the lower plate 63 and, in addition, seals off the chamber within the inner bellows 59 from the atmosphere. The outer diameter of the lower plate 63 is only slightly less than the inner diameter of the tube 11 so that the plate 63 fits nicely there-within and after the displacement means 22 has been positioned within the tube 11, the bottom of the tube 11 is necked over to provide a reentrant flange portion 76 which holds the displacement means in place. Preferably, the flange 76 is seam welded to the plate 63.

In order to guide the displacement means 22 within the tube 11 while insuring a path for liquid flow between the input duct 20 and the upper portions of the chamber, the principal outside diameter of the upper plate 62 is considerably less than the inner diameter of the inner tube 11 and a plurality of protrusions or ears 78 extend radially out from the periphery of the plate 62 and slidably ride against the inner wall of the tube 11 as the displacement means 22 is expanded and contracted. In addition, a guide rod 80 is attached to the center of a bellows cap 82. The cap 82 has a dependent annular

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flange 83 which is welded to the adjoining face of the intermediate portion of the upper plate 62 and an insulating washer 84 is received in a portion of reduced cross-section at the upper end of the rod 80 and slidably rides against the inner face of the electrode 17. In this manner axial movement of the bellows assembly of the displacement means 22 is assured as it is expanded and contracted in accordance with the fluid supplied thereto through the member 71, and the transfer of heat is reduced by the air space provided between the cap 82 and the plate 62.

As is indicated hereinbefore, it is desirable to automatically control the supply of liquid to the chamber through the duct 20 so as to maintain a substantially fixed amount of liquid in the chamber irrespective of variations in the quantity of vapor generated. In prior art generators of the type in which electrodes are maintained in direct contact with the liquid to be vaporized, one or more feeler electrodes are fixedly positioned with respect to the electrodes and thereby maintain a fixed amount of water or liquid in the chamber. In the present case where the level of liquid in the chamber is determined both by the addition of liquid to the chamber and by the condition of contraction of the displacement means 22, it is necessary to movably mount the electrodes so that as they are lifted toward the top of the chamber as the displacement means 22 is expanded to raise the level of liquid in the chamber and to be lowered when the displacement means 22 is contracted so as to lower the level of liquid in the chamber. Consequently, the feeler electrodes may be used in conjunction with an electrically operated valve to maintain a fixed quantity of liquid in the chamber. If, however, the electrodes were to be fixedly positioned with respect to the heating electrodes as is the case in the prior art generators, whenever the displacement means 22 are contracted, liquid will be fed into the system irrespective of whether or not such is necessary to replenish the amount previously vaporized.

Therefore, and in accordance with an important aspect of this invention, a pair of liquid level feeler electrodes 87 and 88 are slidably mounted for vertical movement within the chamber and the vertical position thereof in the chamber is controlled by the displacement means 22. As best shown in FIG. 3, the electrodes 87 and 88 are fixedly mounted at different heights in accord with well known practice to prevent chattering of the valve which controls the supply of liquid to the chamber. It has been found desirable to connect the electrodes 87 and 88 in such a manner that they follow the movement of the displacement means 22, but since the effective area of the displacement means 22 is appreciably less than the cross-sectional area of the chamber, a simple direct connection cannot be provided between the displacement means 22 and the electrodes 87 and 88. Therefore a lever arrangement is provided whereby a given vertical movement of the top of the displacement means 22 is followed by a proportionally less vertical movement of the electrodes 87 and 88. In this manner, the electrodes 87 and 88 maintain a fixed quantity of liquid in the chamber irrespective of the condition of contraction of the displacement means 22.

Referring particularly to FIGS. 1 through 4, a cylindrical tube 90 depends into the chamber, is concentric with the electrodes 12-17 and is electrically insulated therefrom. As shown, the tube 90 is provided with a flange 91 which is co-planar with the lip 49 on the tube 11 and seats on the gasket 53 above the inner ring 46. Also, the tube 90 extends below the bottom of the electrodes 12-17 so as to provide a stop against which the plate 62 abuts when the displacement means is fully expanded and thus prevents short circuiting of the electrodes 12-17 by the displacement means 22. Slidably mounted on the side of the tube 90 is a feeler electrode support assembly 92 which includes an arcuate base plate 93. The inner surface of the plate 93 substantially con-

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forms to the outer surface of the tube 90 and a first clamping member 94 is attached thereto by any suitable means, such, for example, as welding. The member 94 has a pair of arcuate recessed intermediate portions 95 and 96 into which the electrodes 87 and 88 are partially received and clamped in place by means of a second clamping member 97 which is also provided with arcuate intermediate portions which overlie the electrodes 87 and 88. As best shown in FIG. 4, the clamping members 94 and 97 are fastened together by means of a nut and bolt assembly 98, thereby to rigidly clamp the electrodes 87 and 88 thereto. The assembly 92 is slidably attached for relative vertical movement to the tube 90 by means of a pair of rivet assemblies 100 and 101 which extend through suitable apertures in the plate 93 and which are respectively received in keyhole slots 102 and 103 in the tube 90. The keyhole slots 102 and 103 are provided so as to facilitate assembly of the plate 93 and the attached parts to the tube 90.

A twisted swing type connector 105 is pivotally attached to the plate 93 by means of the same rivet assembly 101 which slidably attaches the bottom of the plate 93 to the tube 90 and the downwardly extending portion of the connector 105 is apertured at 106 to receive an annular lever arm 107. The arm 107 is pivotally supported in a fulcrum bracket 109 which is attached by means of a plurality of legs 110 to the tube 90. The legs 110 extend through suitable apertures (not shown) in the tube 90 and, if desired, a plurality of sets of such apertures may be provided at spaced locations on the tube 90 so as to permit adjustment of the position of the fulcrum bracket 109 with respect to the location of the connector 105. The ring 107 is connected as a second class lever and, therefore, the end which is substantially diametrically opposite the bracket 109 is driven by the displacement means 22. Therefore, it is provided with a wheel 112 which rides on the upper surface of the plate 62 and which is held in engagement with the plate 62 by means of a U-shaped bracket 114 which is welded at its underside to the lower side of the plate 62.

Therefore, for example, as the displacement means 22 is contracted and the plate 62 moves downwardly in the chamber, the ring 107 pivots counterclockwise as viewed in FIG. 3 about its pivotal axis which causes a corresponding but lesser downward movement of the bracket 105. The plate 93 and the electrodes 87 and 88 thus move downwardly. For example, if the wheel 112 is located diametrically opposite the median plane of the fulcrum bracket 109 and the twisted bracket 105 is centrally disposed between the two, the electrodes 87 and 88 move half the distance that the tops of the bellows 59 and 60 move.

While in the illustrated embodiment of the invention the electrodes 87 and 88 are slidably mounted on the tube 90 and the fulcrum 109 is also mounted on the tube 90, if desired, one or both of these parts may be slidably mounted on the inner wall of the tube 11, which has the advantage that the probe level may be readily adjusted from outside the generator during operation thereof.

In order to provide means for electrically connecting the movable feeler electrodes 87 and 88 to an external control circuit for automatically controlling the supply of liquid through the duct 20 to the chamber 11, there is provided in accordance with the present invention and as best shown in FIG. 5 a slidable connector assembly 115. Inasmuch as the connector means for each of the electrodes 87 and 88 are identical, only the assembly for the electrode 87 is described in detail.

Referring to FIG. 5, it may be seen that the electrode 87 comprises a tubular contact member 116 which is formed of any good conductor which is not subject to oxidation under normal conditions such, for example, as rhodium or rhodium plated stainless steel. As shown, the tube 116 has a spherical lower end 117 for insuring good contact with the liquid. The upper portion of the tube

116 is tightly positioned within the sleeve 118 of a good insulating material such, for example, as Teflon and a curved, flexible conductive wire 120 is positioned within the bore of the tube 116 and secured in the bottom thereof by means of a suitable material such, for example, as silver solder 121. Another tube 123, which is preferably constructed of the same material as the tube 116, and to which the external electric circuit connection is made, is provided with a threaded upper end 124 which is soldered over at 125 to provide a vapor-tight seal. The tube 123 is tightly received in a sleeve 127 of insulating material which may be similar to the sleeve 118 and which is provided with an integral annular flange 128. The flexible conductor 120 extends into the bore of the tube 123 and rides against the inner surface thereof to provide an electric connection between the upper and lower parts of the assembly. Therefore, as the electrode 87 is moved up and down with respect to the heating electrodes, the upper end of the conductor 120 slides along the inside of the tube 123 and effects good electrical contact therewith.

In order to support the tube 123 and its associated sleeve 127 in a fixed position in the chamber, the inner clamping ring 46 is provided with a hole 130 having a diameter substantially the same as the outside diameter of the sleeve 127 and through which the tube 123 and sleeve 127 extend. The hole 130 is counterbored at 131 to provide an enlarged recess in which the flange 128 is positioned. A pair of annular sealing gaskets 132 and 133 are positioned on opposite sides of the flange 128 and an apertured pusher bar 135 having a head 136 thereon is positioned over the sleeve 127 and rests against the top of the upper gasket 133. The upper clamping ring 47 is provided with a threaded bore 137 through which the tube 123, sleeve 127 and part of the pusher bar 135 extends. A screw 139 having a central aperture for reception of the sleeve 127 and tube 123 is threaded into the bore 137 and pushes the head of the bar 135 into engagement with the gasket 133, thereby to effect a seal which prevents the escape of the generated vapor around the sleeve 127.

Referring to FIG. 8, there is shown in somewhat schematic form an alternative embodiment of the present invention wherein there is provided a displacement means 140 which comprises inner and outer annular bellows chambers 141 and 142, the bellows of which are supported from the top of the steam generating chamber and which, therefore, depend into the chamber. With this arrangement the height of the generator may be reduced appreciably from that illustrated in the embodiment of FIGS. 1-7 wherein the displacement means is located at the bottom of the chamber beneath the electrodes.

In the event that the steam generator 10 is used in connection with hard water which may contain a considerable percentage of minerals such as calcium which would cause liming of the heating electrodes 12-17, there is provided, in accordance with another aspect of the present invention and as shown in FIG. 9, an electrode cleaning arrangement which comprises a plurality of concentric annular wipers 150 which are positioned in the spaces between the electrodes 12-17. The wipers 150, which are formed of an insulating material, such, for example, as Carborundum are attached together by means of a rod 151 which extends diametrically through the rings 150 and which is slidably received in grooves in the electrodes 12-17 and insulated from all but the outer electrodes. If desired, the bolt 151 may be guided for sliding movement by the tube 90, in which case it would be insulated from all of the electrodes. The bolt 151 is provided with a head 152 and a nut and washer assembly 153 to prevent endwise displacement thereof and, therefore, to prevent disassembly of the unit. The rod 151 extends through an aperture 155 in the guide bar 80 so that as the bar 80 is moved up and down in accordance with the movement of the displacement means 22 the wiper rings 150 ride up and down against the adjoining walls of the electrodes and thus scrape them clean.

Refer now to FIG. 7 for a consideration of the operation of a system in which the steam generator of the present invention is included. As there shown, the output duct 21 of a steam generator 10 is connected to an output line 163 which may be connected to any suitable load (not shown) such, for example, as an autoclave. A pressure responsive switch 168 is connected in the output line 163 so as to control the operation of a solenoid operated three-way valve 165. The valve 165 is adapted to connect the tube 71 to a water main 161 or to a sewerage line 170 and the valve 165 and switch 168 are so connected that when the pressure in the output line 163 exceeds a predetermined value the valve 165 is operated to vent the chamber within the bellows 59 to the sewerage line 170 and when the pressure in the line 163 falls below a lesser predetermined value, the valve 165 is operated to connect the chamber within the bellows 59 to the water main 161. In this manner, as the pressure in the output line 163 falls below a desired predetermined level the displacement means 22 is operated to raise the level of water in the generator and thereby to cause the generation of a greater quantity of steam; once that a predetermined pressure is reached the displacement means 22 is automatically contracted to reduce the level of water in the chamber 11 and thus to reduce the quantity of steam generated. In this way an output pressure having a value within the limits set by the two operating points of the switch 168 is provided.

In order automatically to replenish the amount of water which is vaporized and passed out of the generator 10 through the duct 21, the electrodes 87 and 88 are connected to the input of a control circuit 171, the output of which controls the operation of a solenoid operated valve 160. When the level of water in the chamber is such that the water is out of contact with the lower feeler electrode 87, the valve 160 is operated so as to connect the input duct 20 to the water main 161, and when the level of water in the chamber 11 is such as to contact the upper feeler electrode 88 the valve 160 is operated to disconnect the valve from the water main 161.

Considering the operation of the system shown in FIG. 7, let it be assumed that the generator 10 there-shown has just been connected to a load and that the control circuit 171 and the heating electrodes 12-17 are initially energized. At this time, because there is not enough liquid in the chamber for it to contact the lower feeler electrode 87, the solenoid valve 160 is actuated to connect the water main 161 to the duct 20. Water is thus fed to the chamber of the generator 10. This continues until the water engages the upper feeler electrode 88, at which time the solenoid valve 160 operates to disconnect the water main 161 from the duct 20 thereby to interrupt the flow of liquid into the generator. Since there is no pressure developed in the output line 163 until the liquid engages the heating electrodes 12-17, the pressure responsive switch 168 is not actuated and the three-way valve 165 is in the position wherein the chamber of the bellows 59 is connected to the water main 161. Therefore, water flows under pressure through the tube 71 into the bellows 59 to expand the displacement means 22 and thereby to raise the electrodes 87 and 88 to their highest level. The water thus rises to its maximum level and a maximum contact area is provided between the heating electrodes 12-17 and the water. Steam is then generated at a maximum rate until the pressure in the output line 163 reaches the predetermined value, at which time the switch 168 is actuated. Actuation of the switch 168 operates the valve 165 to disconnect the bellows 59 from the water main 161 and to connect it to the sewerage line 170. Because the pressure in the generator 10 now exceeds atmospheric pressure, the displacement means 22 is contracted by the force of the steam in its limiting position as controlled by the top of the tube 71. Further contraction of the displacement means 22 is terminated and the electrodes 87 and

88 are thus positioned at their lowest level. At this time it is preferable that the level of water be slightly below the ends of the electrodes 12 and 17 so that no steam is generated. This condition of operation of the generator 10 continues to exist until the pressure in the output line drops below the minimum operating value of the switch 168. In a successful reduction to practice of the present invention, the pressure values of operation of the switch 168 differ by two pounds. When this lower value of pressure is reached, because, for example, of losses in the system or for other reasons, the switch 168 again operates the valve 165 so that water from the main 161 again operates the bellows 59 to expand the displacement means 22 to its maximum position in engagement with the lower end of the tube 90. A maximum quantity of steam is thus generated until the switch 168 is again operated.

It may thus be seen that the steam generator 10 of the present invention provides positive means for maintaining a maximum liquid level in the chamber when a maximum quantity of steam is required while providing simple means for providing relatively large quantities of steam.

While the invention has been described by means of particular embodiments thereof it will be understood that those skilled in the art may make many changes and modifications without departing from the true spirit and scope of the invention, and accordingly, all such changes and modifications which fall within the true spirit and scope of this invention are intended to be covered in the appended claims.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A vapor generator comprising at least one heating electrode disposed within a vaporizing chamber, and means for controlling the level of a liquid in said chamber, said means comprising a bellows immersed in said liquid and motor operated means for selectively expanding said bellows to adjust the level of liquid in said chamber, thereby to control the quantity of vapor generated.

2. A vapor generator comprising a vaporizing chamber for containing a quantity of liquid to be vaporized, at least one heating electrode disposed within said chamber, said electrode being displaced a substantial distance from the bottom of said chamber, and motor operated displacement means mutually exclusive of said liquid and disposed within said chamber near the bottom thereof and immersed in said liquid for controlling the level of said liquid in said chamber and thus the amount of said liquid in contact with said electrode.

3. A vapor generator as set forth in claim 2 which further includes means for maintaining a substantially constant quantity of said liquid in said chamber.

4. A steam generator comprising a container, a vaporizing electrode disposed within said container, means for controlling the supply of water to said container, displacement means disposed within said container for controlling the level of water in said container, said displacement means being immersed in the water in said container, means for connecting a source of pressurized fluid to said displacement means, said pressurized fluid being mutually exclusive of the water in said container, and means controlling the supply of fluid to said displacement means in response to the pressure in said container.

5. A vapor generator comprising a vessel for holding a supply of liquid, a plurality of concentric electrodes depending into said vessel, expandable annular displacement means mounted within said vessel concentric with said electrodes and immersed in the liquid contained in said vessel for controlling the depth of penetration of said electrodes in said liquid, and means for controlling the supply of said liquid to said vessel.

6. A steam generator comprising a vessel, a control valve connected between said vessel and a source of water under pressure, at least one electrode disposed within said vessel, means responsive to the quantity of water in said

vessel for operating said control valve to maintain a constant quantity of water in said vessel, a vapor outlet conduit connected in the upper portion of said vessel, an expandable bellows disposed within said vessel below said electrodes, valve means for selectively connecting the chamber of said bellows to said source of water or to a drain line, and pressure responsive means connected with said conduit for operating said valve means to connect said bellows chamber to said source of water when the pressure in said vessel is less than a predetermined value and to connect said bellows chamber to said drain line when the pressure in said vessel is greater than a predetermined value.

7. In a vapor generator, a vessel, at least one electrode disposed within said vessel, expandable displacement means mounted within said vessel, and means connected to said displacement means for movement therewith to scrape the surface of said electrodes to remove any material deposited therein.

8. A vapor generator comprising at least one heating electrode disposed within a vaporizing chamber, said chamber being adapted to hold a supply of liquid in which said electrode is immersible, a fluid operated bellows mounted in said vaporizing chamber at least partially below the level of liquid disposed in said chamber and having an expandable fluid receiving chamber therein isolated from said vaporizing chamber, and means for adjusting the supply of fluid to the bellows chamber thereby to control the liquid level in said vaporizing chamber.

9. A vapor generator as set forth in claim 8 wherein said last-named means is responsive to the pressure in said vaporizing chamber.

10. A vapor generator as set forth in claim 9 wherein said means comprises a pressure sensitive control valve.

11. A vapor generator comprising a vaporizing chamber, a heating electrode fixedly positioned in said chamber, and means for controlling the level of a liquid in said vaporizing chamber, said means including a bellows disposed in said vaporizing chamber below said liquid level, and motor means for selectively expanding and contracting said bellows to control the quantity of vapor generated.

12. Apparatus for generating steam, comprising a vaporizing chamber having a steam outlet near the upper end thereof, a plurality of concentric heating electrodes depending into said chamber, means for selectively connecting said chamber to a source of water, a displacement means mounted in direct communication with said vaporizing chamber for adjusting the volume of said chamber below said electrodes, and control means selectively connecting said source of water to said displacement means to control the size of said volume.

13. Apparatus as set forth in claim 12 wherein said displacement means comprises a double walled bellows.

14. Apparatus as set forth in claim 12 wherein said control means is positionable to connect said bellows chamber to a relatively low pressure area thereby to permit compression of said displacement means by the pressure within said vaporizing chamber.

15. Apparatus as set forth in claim 14 wherein at least three heating electrodes are provided for and alternate ones of said heating electrodes are electrically and mechanically connected together.

16. A vapor generator comprising a vaporizing chamber, at least one heating electrode disposed in said chamber, said electrode being displaced from the bottom of said chamber, and pressure sensitive means for controlling the level of liquid in said chamber at one of two predetermined levels, said liquid being maintained above a first level in contact with said electrode when the pressure in said chamber is below a predetermined value, said liquid being maintained below a second level out of contact with said electrode when said pressure is above said predetermined value, said pressure sensitive means including an expandable displacement mechanism disposed in

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said chamber beneath said electrode and immersible in
said liquid for controlling the level thereof.

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