

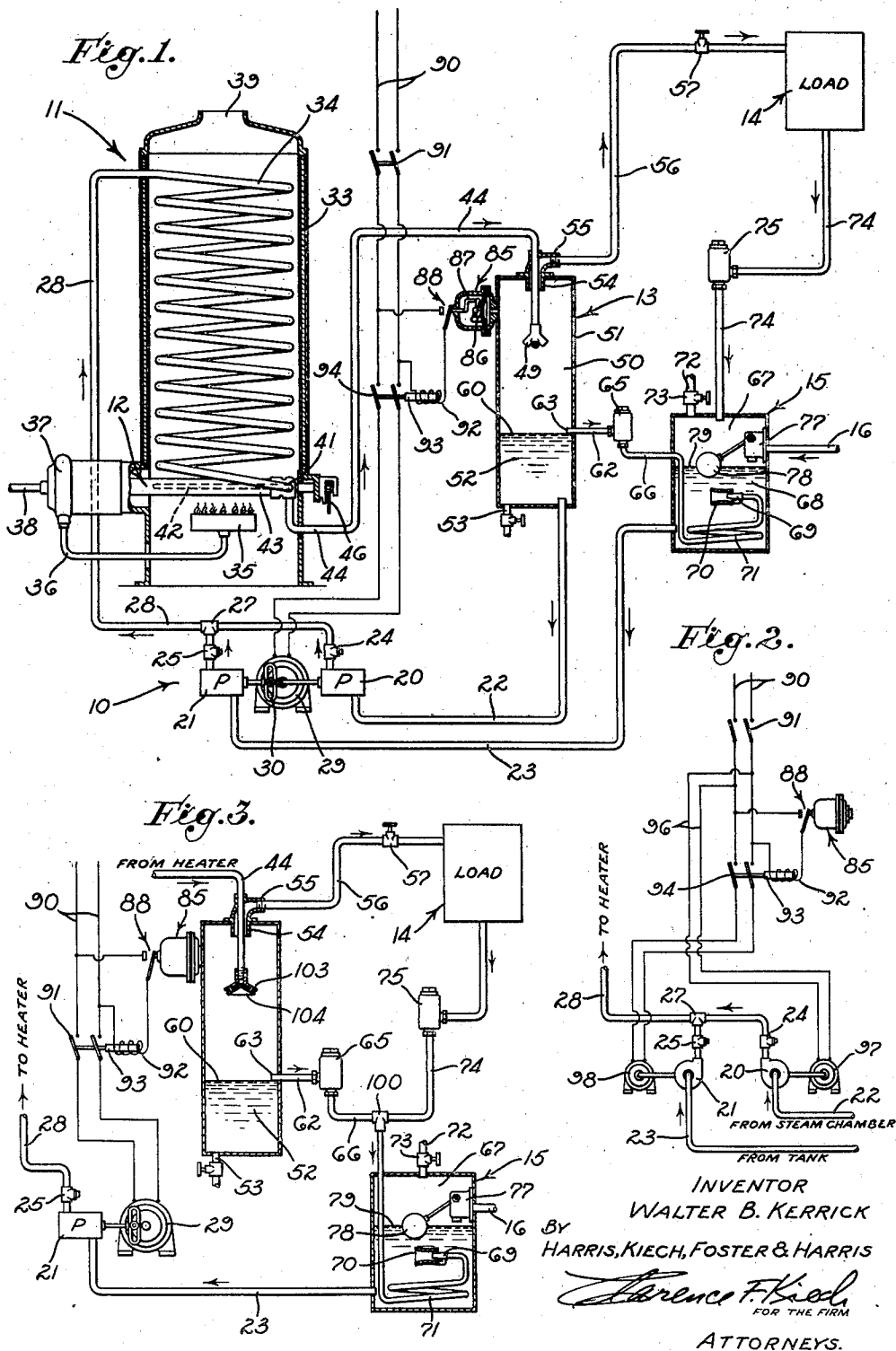
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PROCESS AND APPARATUS FOR GENERATING STEAM

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PROCESS AND APPARATUS FOR
GENERATING STEAM

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My invention relates to the generation of steam and is believed to be novel both in its process steps and in the novel combinations of elements used in the structure.

5 In general, the invention comprehends pumping into a heating zone an amount of water greater than that required to meet the steam demand, heating the water to a steam-forming temperature at which some steam will flash
10 therefrom when the pressure is reduced or at which some steam is formed in the heating zone, avoiding the application of any such amount of heat as would vaporize the entire stream, separating steam from the excess unvaporized water
15 in a steam chamber, and circulating water from the steam chamber to the intake of the heating zone. Preferably, the heating zone comprises an elongated passage so designed with reference to the amount of water delivered thereto that any
20 steam formed therein will be kept uniformly mixed with the water as long as the flow continues.

It is an object of the present invention to provide a steam-generating process and apparatus in
25 which ebullition conditions are ideal, and in which the steam is produced substantially free of entrained minerals, even though the size of the steam-producing unit is small. This may be accomplished by jetting the heated stream into the
30 upper end of the steam chamber in such manner as to form myriads of small water droplets which enormously increase the area of water in contact with the steam.

It is another object of the present invention
35 to provide a novel process and apparatus for controlling the amount of water in the steam chamber.

A further object is to withdraw water from the steam chamber and add make-up water thereto
40 at reduced pressure, after which the combined water is pumped into the system for circulation therethrough.

Another object of the invention is to withdraw all water from the steam chamber tending to rise
45 above a predetermined position which represents the maximum desired position of the surface of the body of water therein.

Another object of the invention is to conduct the water thus withdrawn to a tank or chamber
50 and add make-up water to this chamber in controlled amount.

The load may be of such type as to condense all or a portion of the steam, thus making available condensate for return to the heating system,
55 and it is an object of the invention to return all

or a portion of such condensate in heat-transferring relationship with the water withdrawn from the steam chamber and, preferably, to return such condensate to a second chamber which receives at least a portion of the excess water reaching the steam chamber.

Another object of the invention is to provide a heat transfer between the excess water circulated through the system and the make-up water added thereto.

Certain of the control features of the invention are also believed to be novel in themselves or in combination with other elements of the invention. For example, it is an object of the present invention to control the addition of make-up water in
10 such manner that the water thus added is sufficient, over a period of time, to meet the steam demand, and another object resides in the supply of the make-up water to a second chamber separate from the steam chamber to maintain a sub-
15 stantially constant amount of water in the former.

Another object of the invention is to provide a steam-generating system in which the pumping action can be controlled automatically to prevent
25 wastage of heat during idling periods or periods of low steam demand.

Another object of the invention is to provide a steam-generating system in which the thermal conditions of the stream discharged into the
30 steam chamber can be maintained through control of the heat, and in which any reduction in pumping action will be automatically compensated by a reduction in the amount of heat transmitted to the stream.

Another object of the invention is to provide a steam-generating system in which local overheating is prevented during continued operation and in which scale formation on the walls of the heating zone is substantially eliminated, thus insuring long life of equipment and constancy of
40 operating conditions.

Further objects and advantages of the invention will be made evident from the following description, taken in conjunction with the appended
45 drawing.

Referring to the drawing:

Figure 1 is an elevational view diagrammatically indicating one embodiment of the invention.
50

Figure 2 illustrates a modification of the pump control shown in Figure 1.

Figure 3 diagrammatically illustrates an alternative system for combining the water taken from the steam chamber with the make-up water
55

and, if desired, any condensate returned from the load, and also indicates a modified pumping arrangement particularly adapted to this alternative system.

Referring particularly to Figure 1, the apparatus, in general, includes a pump means 10 for forcing water through a heater 11 provided with a heat-control means 12 and discharging a heated stream into an accumulator or closed container 13. Steam is withdrawn from the upper end thereof and supplied to a load 14. The excess water collecting in the accumulator 13, together with necessary make-up water, is fed to the pump means 10 for return to the heater 11. A tank 15 is provided to receive at least a portion of this excess water and the make-up water can be added thereto from any water supply, indicated as a pipe 16.

In the embodiment shown in Figure 1, the pump means 10 is shown as including two pumps respectively termed, for convenience, a circulating pump 20 and a feed water pump 21, respectively withdrawing water from the accumulator 13 through a pipe 22 and from the tank 15 through a pipe 23. In some instances, the pump 20 can be dispensed with or rendered inoperative. These pumps may be of any desired type but constancy of inflow to the heater 11 during operation of the pumps can be insured by using pumps of the displacement type which discharge a substantially constant amount of water, irrespective of the pressure head developed in the heater or subsequent equipment. Check valves 24 and 25 are provided to prevent any reverse flow and, if desired, may be formed as a part of the pumps 20 and 21. The streams respectively delivered by the pumps 20 and 21 combine at a junction 27 disposed in a pipe 28 which delivers the combined water to the heater 11. It will be clear, however, that the streams withdrawn from the accumulator 13 and tank 15 may be combined in various manners with regard to the pump means employed and need not come together on the discharge side. It will be clear, likewise, that the capacities of the pumps 20 and 21 need not be equal, and various expedients can be used for determining the relative amounts of water pumped by these pumps. If displacement pumps are used, they can be of the double acting or single acting type, though the former is preferred. As shown in Figure 1, these pumps are driven by a common drive means indicated as an electric motor 29, but it should be clear that independent drives for these pumps can be used, as hereinafter shown, and that the interconnecting mechanism between the drive and the pumps can be of any desired type. For illustrative purposes, a Scotch yoke means 30 is shown in this connection.

The function of the heater 11 is to heat the stream of water delivered thereto from the pump means 10 to a steam-forming temperature. By this term, I have reference to such temperature as will permit steam to form either in the heater itself or in the accumulator 13, or in both. The preferred mode of operation contemplates the generation of some steam in the heater 11 while distinctly avoiding any such heating as would vaporize the entire stream. In this mode of operation, it is very desirable to maintain any steam generated in the heater 11 in intimate mixed relation with the water and to avoid any separation of such steam as might form steam pockets or slugs of steam in the discharge. These functions can be performed by the type of heater shown.

This heater 11 is shown as including a housing 33 in which is disposed a tubular unit, shown as being in the form of a coil 34, and which provides an elongated heating zone communicating with the pipe 28. The use of pancake coils will be found desirable in this respect and, in the event of heating by products of combustion, it is distinctly preferred to move the stream of water into the coolest zone so that it flows toward the source of heat. While any source of heat can be used without departing from the spirit of the invention, a burner 35 is diagrammatically shown in this regard and receives fuel through a pipe 36, as controlled by a valve means 37 fed by a pipe 38. The products of combustion from the burner 35 move upward in the housing 33 and are discharged through a flue 39.

To prevent wastage of heat and insure constancy of operation under varying steam demands and correlation between the heat supplied to the stream and the amount of water delivered to the heater, I provide a heat-control means 12 of any suitable type responsive to the thermal condition of the stream adjacent the discharge end of the elongated heating zone and operatively connected to the valve 37. The details of the particularly-described heat-control means are not, per se, a part of the present invention but the means 12 is novel in the combination hereinafter described. The constructional details of this heat-control means are shown in my Patent No. 1,968,525. Suffice it to say that the heated stream discharging from the tubular unit 34 enters a passage of a head member 41 which communicates with an inner pipe 42 disposed within an outer pipe 43 so that the stream moves leftward through the inner pipe 42 and then reverses its direction of movement, with resulting turbulence, and moves rightward through an annular space between the inner and outer pipes 42 and 43 to return to the head 41 and be discharged through a pipe 44. It is usually advantageous to use an inner pipe 42 of slightly smaller internal diameter than the pipe comprising the tubular unit 34 whereby some throttling action is obtained and the stream is permitted to expand while moving along the inner pipe 42 or after discharge therefrom. The outer pipe 43 is formed of a material having good heat conductivity properties and is disposed close to the burner 35 so as to be directly under the influence of the flame. The left end of this outer pipe 43 is operatively connected to the valve means 37 in such manner that the amount of fuel passing through this valve means increases and decreases in response respectively to a contraction or expansion of the outer pipe 43, as disclosed in my patent supra.

Correspondingly, the amount of heat supplied to the tubular unit 34 in this embodiment of the invention is controlled in response to the temperature, and thus the expansion and contraction with changes in temperature, of the outer pipe 43. It will be clear that this outer pipe receives heat from the burner and acts to transmit heat to the annular stream moving therethrough. This being the case, the outer pipe 43 tends to be heated by the burner and cooled by the stream, and this pipe is thus at a temperature intermediate the flame and the stream flowing therein. Several factors, in addition to those mentioned above, control the temperature of this outer pipe, including the rate at which heat is absorbed from the burner, the rate of heat transmission through the outer pipe, etc., but, pri-

marily, the temperature of this pipe is dependent upon the rate at which heat is taken therefrom by the stream. This, in turn, depends upon the amount of steam present in this stream.

5 The presence of material amounts of steam in the annular stream decreases the heat transmission from the pipe to the stream and, in effect, this device can be made to operate as a steam-proportion controller to maintain substantially constant the proportion of steam present in the stream so long as the pressure remains substantially constant. It thus differs from an ordinary thermostat. As described in my patent supra, an adjustment means 46 controls the position of the head 41 relative to the valve means 37 so that, by turning this adjustment means, the proportion of steam present in the outgoing stream can be changed to a new value, after which the heat-control means will maintain this value substantially constant so long as the pressure in the heat-control means remains substantially constant.

While a particularly advantageous heat-control means has been shown in Figure 1, it should be clear that the invention is not limited thereto. Other heat-control means can be used in place of the particular means shown. In some instances, no automatic heat-control means need be used, in which event the fire can be manually controlled with reference to the amount of water pumped through the coil and the temperature thereof, or a predetermined correlation of fire and amount of water can be employed.

Pressure variations in the heat-control means and, in fact, in the tubular unit 34 can be reduced very materially by throttling the stream as it discharges from the pipe 44 into the accumulator 13. This can best be accomplished by use of a nozzle 49 which builds up a considerable friction head as the stream moves therethrough and is released into the accumulator 13 though, in some instances, the throttling action can be small or negligible, if desired. As shown, this nozzle is of the multi-orifice type, the combined areas of the orifices being somewhat less than the area of the opening provided by the pipe 44.

The function of the accumulator 13 is primarily to separate the steam and the water, whether this steam was formed partially ahead of the nozzle 49 or by flashing in the accumulator 13. This accumulator provides a steam chamber 50 bounded by a closed container 51 capable of withstanding pressure. In the lower end of the steam chamber, a body of water 52 collects and the upper portion of this steam chamber comprises a steam zone into which the nozzle 49 discharges. By permitting the stream to expand upon discharge into the steam chamber, or by use of other expedients, the unvaporized liquid in the stream is suddenly broken up into very small droplets, thus greatly increasing the area of contact between the steam and the water and thus facilitating liberation of the steam and providing such efficient ebullition that the steam withdrawn to meet the demand has a negligible mineral content, often not more than two or three parts per million. The excess unvaporized water moves downward in the steam zone to form and maintain the body of water 52, and carries with it the minerals present in the water used for meeting the steam demand, these minerals being largely deposited in the lower end of the container 51 from which they can be periodically withdrawn through a blow-off 53. This body of water is maintained at the temperature corre-

sponding to the boiling point at the pressure existing in the steam chamber 50 and is available for generation of steam should this pressure be lowered, as by sudden increase in steam demand.

Steam is withdrawn from the upper end of the steam chamber 50 by any suitable means. One advantageous way of withdrawing the steam is through a conduit 54 disposed concentric with respect to the downward-extending portion of the pipe 44, this conduit forming a part of an elbow 55 from whence the steam moves through a pipe 56 to the load 14. Any desired throttle means may be used to regulate this discharge of steam. Diagrammatically, a valve 57 is shown in this capacity.

The surface of the body of water 52 is indicated by the numeral 60, and it is very desirable to maintain this surface below a predetermined maximum position to determine the minimum volume of the steam zone thereabove and thus insure the desired ebullition and maintain the desired operating conditions. This result is accomplished in the present invention by a means for withdrawing from the steam chamber 50 any water tending to raise the surface 60 above a predetermined maximum position, which is approximately the position of the surface 60 indicated in Figure 1.

This withdrawal means includes a pipe means 62 providing an entry portion 63 disposed horizontally adjacent the uppermost position of the surface 60 so that any water tending to rise above this entry portion will be discharged through the pipe means 62. A steam trap 65 is provided in this pipe means and serves the function of allowing water to be discharged while preventing any discharge of steam. This steam trap may be of conventional design, for example, of the type including a float which opens a valve discharging into a pipe 66 when the water in the steam trap rises to lift the float. Correspondingly, when the surface 60 is below the entry portion 63, no steam will be discharged into the pipe 66 but any rise of this surface will permit enough water to flow through the pipe means 62 and be discharged through the steam trap 65 into the pipe 66 to determine the uppermost position of the surface 60. If desired, the pressure in the pipe 66 may be considerably lower than that in the pipe means 62 so that, after movement through the valve of the steam trap, some steam may form by flashing.

The excess water moving through the pipe 66 is discharged by any suitable means into a second chamber 67 provided by the tank 15, and a heat transfer is effected between the material of the stream passing through the pipe 66 and a body of water 68 maintained in this tank 15. Various methods of thus transferring heat can be used without departing from the spirit of the invention. The pipe 66 is shown as extending downward into the body of water 68 and the water flowing in this pipe may be discharged directly into the body of water, or it can be discharged at a higher elevation and move downward into the body of water. If desired, an injector-type water heater may be used if a submerged discharge is employed and this is shown as including a nozzle 69 discharging into a sleeve 70 of the Venturi type disposed around this nozzle so that the velocity of the stream draws some of the water from the body 68 into the sleeve to give a desirable mixing action, with consequent very efficient heat transfer. In addition, the pipe 66 is shown as including a coil 71 dis-

posed in the body of water 68 so that a heat transfer takes place even before discharge from the nozzle 69. It will be clear that either or both of these systems can be used to transfer heat to the body of water 68 and thus avoid heat losses.

The tank 15 is shown as including a vent 72 equipped with a valve 73. If it is desired that the pressure in the tank 15 should be substantially atmospheric, this valve 73 can be opened or an open-top tank can be used. On the other hand, it is within the contemplation of the present invention to maintain a superatmospheric pressure in the tank 15 during normal operation, or to permit wide pressure variations therein, in which event the valve 73 may be closed. In the event that the pipe 16 communicates with a domestic water supply, it is usually desirable to open the valve 73 and maintain atmospheric pressure in the tank 15.

If desired, all or a portion of the condensate from the load 14 can be returned to the tank 15 through a pipe 74. If all of the steam is condensed, the pipe 74 will return to the tank 15 an amount of water corresponding to that required to meet the steam demand, and no make-up water will be added to the system except as required to compensate for any leakage in the system. It is usually desirable to dispose a steam trap 75 in the pipe 74 so that only condensate is delivered to the tank 15. This steam trap may be of the type previously described or may be of a type which additionally cools the stream so as to insure that no substantial amount of steam will be delivered to the tank 15 and wasted if this tank is open to the atmosphere. On the other hand, various means can be used for returning condensate from the load 14 to the tank 15 without departing from the spirit of the invention. One such possibility is shown in Figure 3 in which the condensate is combined with the excess liquid drawn from the steam chamber before discharge into the tank 15.

It is desirable to add to the tank 15 an amount of make-up water sufficient to meet the steam demand. In the event of use of the condensate return pipe 74, the amount of make-up water delivered by the pipe 16 need be only sufficient to compensate for any steam not condensed. The load 14 often is of such character as not to make available condensate from the entire amount of steam delivered thereto, in which event make-up water is added through the pipe 16 to compensate for this. A convenient and very satisfactory way of controlling the make-up water supplied through the pipe 16 is to use a valve 77 controlled by a float 78 and acting in such manner as to maintain the surface of the body of water 68 substantially constant, this surface being indicated by the numeral 79. Thus, when this surface drops, the float 78 will lower to permit make-up water to enter through the valve 77 until the surface 79 is raised to the desired point.

The invention comprehends the use of a recirculation means for returning to the heater any excess water, not used for supplying the steam demand, and which is delivered to the steam chamber 50 of the accumulator 13. As will be explained with reference to Figure 3, all of this excess water may move through the pipe means 62 but, in the form of the invention shown in Figure 1, excess water can move from the steam chamber either through this pipe means 62 or through the pipe 22 which opens on the lower

portion of the body of water 52 and communicates with the intake of the pump 20. This pump 20, if of the constant displacement type, can thus withdraw from the steam chamber a substantially constant amount of the excess water. The capacity of the pump 20 is preferably such that it will not withdraw all of the excess water, the pipe means 62 being relied upon in this connection so that the surface 60 will never rise above the entry portion 63. As will be clear from Figure 1, the pipe 23 communicating with the intake of the pump 21 is in open communication with the body of water 68 in the second chamber 67 of the tank 15. Thus, any water moving from the steam chamber through the pipe means 62, together with any condensate delivered to the tank 15 through pipe 74 and any make-up water delivered through the pipe 16, can be withdrawn through the pipe 23 and returned to the heater 11 by the pump 21.

If desired, the system can be continuously operated to meet a varying steam demand without stopping the pumps for it will be clear that the heat-control means 12 will supply an appropriate amount of heat to meet the steam demand, and the amount of make-up water added to the system will be automatically controlled. However, in the event that the throttle 57 is closed, or in the event of very low steam demands, some heat losses will take place if the pumps are driven continuously as the body of liquid 68 in the second chamber 67 may reach the boiling point at the pressure existing therein. Under such conditions of intermittent supply of steam or wide variations in steam demand to a point where practically no steam is desired at a particular time, I prefer to control the pumping action in such manner that the supply of water to the heater 11 will be reduced until such time as the steam demand increases, the heat being controlled so as to prevent overheating. Various means can be used in this connection without departing from the spirit of the invention, but I find it very satisfactory to start and stop the motor 20 in response to thermodynamic conditions in some portion of the system, for example in the chamber 50 of the accumulator 13. As shown, a pressure switch 85 is used in this connection and includes a diaphragm 86 with a linkage 87 connecting this diaphragm with a switch 88. When the pressure in the steam chamber 50 of the accumulator 13 rises above a predetermined value, determined by the setting of the pressure switch 85, the switch 88 opens to deenergize the motor 20. When the pressure in this steam chamber drops below a predetermined value, determined again by the setting of the pressure switch 85, the switch 88 will again close to start the motor 20. It will be clear, however, that the pressure switch 85, while described with reference to operation under changes in pressure, will operate likewise with changes in temperature in the steam chamber as temperature and pressure conditions therein are, of course, correlated due to the fact that the temperature is at the boiling point of water at the pressure existing. Correspondingly, the means responsive to pressure variations includes, likewise, a means actuated directly by temperature changes, and the term is not used with reference only to a pressure-operated switch.

In Figure 1, the motor 20 is energized from a line 90 including a master switch 91, and the switch 88 is connected in series with a solenoid

winding 92 across the line 90 beyond this master switch. An armature 93 is connected to a switch 94 so that, when the switch 88 closes, the solenoid winding 92 is energized to close the switch 94 and thus supply current to the motor 29. While the embodiment shown in Figure 1 uses a single motor to drive the pumps 20 and 21, it is within the contemplation of the invention to use separate drives therefor and, if desired, to stop the pumping action of only one of the pumps in response to changes in pressure or temperature in the steam chamber 50 of the accumulator 13. In this connection, it is possible to actuate the pump 20 continuously and to start and stop the pump 21 in response to changes in pressure or temperature in the steam chamber 50, the heat being appropriately controlled at all times, whether by manual or automatic means.

Figure 2 shows this manner of controlling the pumps. Here, a branch line 96 conducts current from the line 90 at a point beyond the master switch to a motor 97 which drives the pump 20. A separate motor 98 is used to drive the pump 21 and this motor is connected in circuit with the switch 94 actuated as previously described. Also, in Figure 2, the pumps 20 and 21 are diagrammatically shown as being of the centrifugal type for it will be clear that it is not always imperative to use pumps of the displacement type.

The preferred mode of operation of the device shown in Figure 1 is as follows. The pumps 20 and 21 serve to deliver a substantially constant amount of water to the heater 11, irrespective of the pressure built up therein due to friction in the tubular unit 34, the heat-control means 12, or the nozzle 49, so long as these pumps remain in operation. Correspondingly, there is set up a column of liquid which is progressively heated to a steam-forming temperature under the control of the heat-control means 12. During the time that this stream is heated, it is moving through the elongated heating zone of the tubular unit 34. In the preferred mode of operation, and while the steam demand is large, sufficient heat is applied so as to generate some steam in the lower turns of the tubular unit 34. It is important, however, that any steam generated therein should be maintained uniformly dispersed in the water, thus avoiding the formation of steam pockets, scaling of the elongated heating zone, and non-uniform quality of the stream moving through the pipe 44. If steam is generated in the tubular unit 34, it will be apparent that the volume of the stream increases very materially, with consequent increase in velocity and friction, thus developing a higher friction head against which the pumps 20 and 21 must operate.

Under other conditions of operation, it is not essential to form steam in the lower portion of the tubular unit 34, in which event the device can be used to deliver a stream of superheated water to the nozzle 49, or a stream of superheated water to the annular passage of the heat-control means 12 where, by expansion from the inner pipe 42 or by heat transferred to the annular stream, some steam may be generated. Even then, however, conditions of turbulence are maintained so as to prevent formation of steam pockets or slugs of steam in the stream delivered to the nozzle 49.

Regardless of whether steam has been formed ahead of the nozzle 49, the stream delivered thereto will contain superheated water. When the pressure thereon is reduced (as it must be when moving through the nozzle 49), a portion

of this water will flash into steam. However, the present invention contemplates such control of the heating and pumping actions as will prevent vaporization of all of the water supplied to the heater 11 so that a substantial portion of the water pumped into the heater will comprise an excess not required to meet the steam demand. This excess water increases the velocity in the tubular unit 34, decreases any scaling therein, and makes available an automatic control of the entire system through re-circulation.

The excess unvaporized water accumulates in the steam chamber in the form of the body of water 52 and a portion thereof is returned to the pump 20 through the pipe 22. All water tending to raise the surface 60 above the entry portion 63 moves through the pipe means 62 and to the second chamber 67. The preferred mode of operation involves the maintenance of a somewhat lower pressure in the second chamber 67 than in the steam chamber 50 of the accumulator 13. This permits adding of make-up water, either from an outside source or from the condensate from the load, at a lower pressure than that which exists in the steam chamber. Heat is transferred between the streams entering the second chamber through the pipes 66, 74, and 16, and the resulting water is withdrawn through the pipe 23 to the pump 21 and is then blended at the junction 27 with the warmer water delivered by the pump 20.

In Figure 1, when the steam demand is reduced, as by partially closing the valve 57, the pressure in the steam chamber 50 of the accumulator 13 may rise sufficiently to actuate the pressure switch 85 and thus stop the pumping action of both pumps. The heat-control means 12 will operate almost immediately due to the fact that the cooling stream does not continue to flow through the annular passage between the inner and outer pipes 42 and 43, thus raising the average temperature of the latter and decreasing the fuel supply. If a small amount of steam is withdrawn from the steam chamber through the throttle at this time, the pressure will gradually reduce and steam can be liberated from the body of water 52 in an amount corresponding to the reduction in pressure. When the pressure has dropped to a predetermined point, the pressure switch 85 will close to start the pumps, and the outer pipe 43 of the heat-control means will be cooled by the stream so that the burner will come into operation immediately and will supply an amount of heat required to maintain substantially constant the thermal conditions of the stream discharged into the pipe 44.

During normal operation of the device shown in Figure 1, any large increase in steam demand will lower the pressure in the steam chamber 60 slightly, thus increasing the amount of steam formed by flashing or generated from the body of water 52. The amount of excess unvaporized water will thus decrease and, even though the pump 20 is withdrawing a constant amount of water from the steam chamber, a smaller amount of water will move through the pipe means 62 to the second chamber 67 of the tank 15. The pump 21 is, of course, drawing water from the tank 15 and any reduction in the amount of water delivered thereto through the pipe 66 and not compensated for immediately by an increase in condensate through the pipe 74 will be reflected in a lowering of the float 78 to permit a larger amount of make-up water to enter the second 75

chamber 67 through the pipe 16. Correspondingly, the amount of make-up water will be automatically increased to meet the steam demand.

Should the throttle be entirely closed, the excess water entering the steam chamber will be withdrawn partially through the pipe 22 and partially through the pipe means 62, and the amount of water moving into the second chamber 67 through the pipe means 62 will be sufficient to maintain the float 78 in such position that no make-up water will be required except to compensate for any possible leakage. This will be the mode of operation before the pressure switch opens the circuit to stop the pumping, or if this pressure switch is eliminated from the system, as it can be in many installations.

Correspondingly, the feature of by-passing from the steam chamber any excess water tending to raise the surface 60 above a predetermined maximum is very desirable. It acts not only to prevent an excess amount of water in the steam chamber but also functions to permit addition of make-up water in amount required to meet the steam demand by a very simple means.

The mode of operation of the system shown in Figure 2 is substantially the same as that described with reference to Figure 1 except that, when the pressure in the steam chamber rises above a predetermined point, only the feed water pump 21 is rendered inoperative by the opening of the pressure switch 85. In this instance, no excess water will be introduced into the system from the chamber 67, but water will be withdrawn from the body 52 in the steam chamber 50 by the circulating pump 20 and will continue to be circulated through the system so long as the switch 91 remains closed. The advantage of this arrangement is a saving in the B. t. u. of the latent heat of the water that would otherwise be lost in any excess water that moved through the pipe means 62 to the chamber 67. In effect, this system cuts out the supply of feed and make-up water during the time that the pump 21 is shut off and provides for repeated circulation of the water already in the system by means of the circulating pump 20. However, it will be clear that, even if a reduced amount of water is forced into the heater, the heat-control means 12 will reduce the fuel to such an extent that substantially the same thermal conditions will be maintained in the pipe 44 as were maintained when both pumps were operating.

Referring particularly to Figure 3, the system is substantially the same as that shown in Figure 1, with three exceptions. In the first place, the pipe 22 and the pump 20 are eliminated so that all of the excess water moves through the pipe means 62. In the second place, the stream in the pipe 66 is combined with the condensate in the pipe 74 at a junction 100 before being delivered to the second chamber 67 provided by the tank 15. This combining of the two streams does not modify the action taking place in the subsequent portion of the equipment but serves to transfer heat directly to the condensate. However, in this system, if the second chamber 67 is maintained at atmospheric pressure, some heat losses may occur if the cooling action of the condensate and the make-up water through the pipe 16 is not sufficient to reduce the temperature of the stream in the pipe 66 to a value below 212° F. In the third place, the embodiment in Figure 3 differs from Figure 1 in the use of a different type of restricting nozzle 49. Instead of

using a plurality of orifices, this embodiment provides a conical discharge passage formed by conical plates 103 and 104 to release the stream into the steam chamber and subdivide the water into small droplets. Such a nozzle means, or any single-orifice discharge means, can be used in conjunction with Figure 1 without departing from the invention.

This application is a continuation-in-part of my copending application, entitled "Steam generator," now Patent No. 2,154,683.

Various changes and modifications can be made without departing from the spirit of the invention as defined in the appended claims.

I claim as my invention:

1. A method of generating steam which includes the steps of: moving under pressure along an elongated heating zone a stream of water in excess of that required to meet the steam demand while heating said stream during flow therethrough to a steam-forming temperature; discharging this heated stream into a steam chamber and there separating steam from the excess water and forming a body of said excess water in the lower end of said steam chamber; withdrawing steam from said chamber to meet the steam demand; withdrawing water from said steam chamber at a given maximum level as it reaches said level and at such rate as to prevent a rise in the water level in said steam chamber above said level while precluding the escape of steam at said level; reducing the pressure on at least a portion of said water thus withdrawn; adding to this water while at reduced pressure an amount of make-up water sufficient when vaporized to meet the steam demand; and pumping said water withdrawn from said steam chamber and said make-up water into the intake end of said elongated heating zone to form said stream moving under pressure therethrough.

2. A method of generating steam which includes the steps of: moving under pressure along an elongated heating zone a stream of water in excess of that required to meet the steam demand while heating said stream during flow therethrough to a steam-forming temperature, discharging this heated stream into a steam chamber and there separating steam from the excess water and forming a body of said excess water in the lower end of said steam chamber; withdrawing steam from said chamber to meet the steam demand; withdrawing water from said steam chamber at a given maximum level as it reaches said level and at such rate as to prevent a rise in the water level in said steam chamber above said level while precluding the escape of steam at said level; reducing the pressure on at least a portion of said water thus withdrawn and introducing same into a second chamber which is at a pressure lower than in said steam chamber; adding to this water while in said second chamber an amount of make-up water sufficient when vaporized to meet the steam demand; and pumping said water withdrawn from said steam chamber and said make-up water into the intake end of said elongated heating zone to form said stream moving under pressure therethrough.

3. A method of generating steam which includes the steps of: moving under pressure along an elongated heating zone a stream of water in excess of that required to meet the steam demand while heating said stream during flow therethrough to a steam-forming temperature; discharging this heated stream into a steam chamber and there separating steam from the

excess water and forming a body of said excess water in the lower end of said steam chamber; withdrawing steam from said chamber to meet the steam demand; withdrawing the excess water from said steam chamber while preventing a rise in the water level therein above a desired upper position by withdrawing therefrom through a passage providing an entry portion disposed at a position horizontally opposite the maximum desired water level any water tending to accumulate above said level while precluding the escape of steam at said level through said passage; returning this excess water to the intake end of said elongated heating zone under pressure; and supplying an amount of make-up water to said heating zone to meet the steam demand.

4. A method of generating steam which includes the steps of: moving a stream of water through an elongated heating zone and into a steam chamber at a rate in excess of the steam demand while applying sufficient heat to said stream to cause steam to separate from the water in said steam chamber and leave an excess of unvaporized water which separates from the steam in said steam chamber and tends to collect as a body in the lower end thereof; withdrawing steam from said steam chamber at a rate sufficient to meet the steam demand; withdrawing water from said steam chamber at two points; re-circulating the water withdrawn at one point to said elongated heating zone; adding make-up water to the water withdrawn at said second point in amount sufficient to meet the steam demand; and returning the resulting make-up water and water withdrawn from said steam chamber to said elongated heating zone.

5. A method of generating steam which includes the steps of: moving a stream of water through an elongated heating zone and into a steam chamber at a rate in excess of the steam demand while applying sufficient heat to said stream to cause steam to separate from the water in said steam chamber and leave an excess of unvaporized water which separates from the steam in said steam chamber and tends to collect as a body in the lower end thereof; withdrawing steam from said steam chamber at a rate sufficient to meet the steam demand; withdrawing water from said steam chamber at two points; withdrawing water from one of said points at a predetermined rate and returning the same to said elongated heating zone; withdrawing water at the other point so as to maintain the water level in said steam chamber not substantially higher than a predetermined level; adding make-up water to the water withdrawn at said second point in amount sufficient to meet the steam demand; and returning the resulting make-up water and water withdrawn from said steam chamber to said elongated heating zone.

6. A method as defined in claim 4 including the step of reducing the pressure on the water withdrawn at said second point to a value below the pressure in said steam chamber and adding said make-up water thereto while at said lower pressure.

7. A method as defined in claim 4 including the step of controlling the heating of said stream in response to changes in the thermal conditions of the stream near the end of said elongated heating zone to maintain these thermal conditions substantially constant, and including the step of stopping the withdrawal of water from said chamber from at least one of said points, and consequently the return of this water to said

elongated heating zone, when the pressure in said steam chamber rises above a predetermined value and again starting said withdrawal when the pressure in said steam chamber drops to a predetermined lower value.

8. A method of generating steam which includes the steps of: moving a stream of water through an elongated heating zone and into a steam chamber at a rate in excess of the steam demand while applying sufficient heat to said stream to cause steam to separate from the water in said steam chamber and leave an excess of unvaporized water which separates from the steam in said steam chamber and tends to collect as a body in the lower end thereof; withdrawing steam from said steam chamber at a rate sufficient to meet the steam demand; condensing at least a part of the steam thus withdrawn and returning the condensate to a second chamber; withdrawing water from said steam chamber at a desired maximum level as it reaches said level and at such rate as to prevent a rise in the water level in said steam chamber above said level while precluding the escape of steam at said level and conducting said water to said second chamber to obtain a heat exchange between the water thus withdrawn and said condensate; and withdrawing water from said second chamber and returning it to said elongated heating zone.

9. A method of generating steam which includes the steps of: moving a stream of water through an elongated heating zone and into a steam chamber at a rate in excess of the steam demand while applying sufficient heat to said stream to cause steam to separate from the water in said steam chamber and leave an excess of unvaporized water which separates from the steam in said steam chamber and tends to collect as a body in the lower end thereof; withdrawing steam from said steam chamber at a rate sufficient to meet the steam demand; condensing at least a part of the steam thus withdrawn and returning the resulting condensate to a second chamber while maintaining this second chamber at substantially atmospheric pressure; withdrawing excess water at a given maximum level from said steam chamber at a rate sufficient to prevent the rise of said level above said maximum level and discharging said water into said second chamber while precluding the escape of steam at said maximum level; adding make-up water to said second chamber; and periodically withdrawing said condensate and make-up water from said second chamber and returning same to said elongated heating zone under pressure.

10. A method of generating steam which includes the steps of: moving a stream of water through an elongated heating zone and into a steam chamber at a rate in excess of the steam demand while applying sufficient heat to said stream to cause steam to separate from the water in said steam chamber and leave an excess of unvaporized water which separates from the steam in said steam chamber and tends to collect as a body in the lower end thereof; withdrawing steam from said steam chamber at a rate sufficient to meet the steam demand; condensing at least a part of the steam thus withdrawn and returning the resulting condensate to a second chamber; withdrawing water at a given maximum level from said steam chamber at a rate sufficient to prevent the rise of said level above said maximum level while precluding the escape of steam at said level and conducting said water to said second chamber; adding make-up water to said

second chamber in such amount as to maintain substantially a constant amount of water therein; and pumping water from said second chamber to said elongated heating zone.

11. A method of generating steam which includes the steps of: moving a stream of water thorough an elongated heating zone and into a steam chamber at a rate in excess of the steam demand while applying sufficient heat to said stream to cause steam to separate from the water in said steam chamber and leave an excess of unvaporized water which separates from the steam in said steam chamber and tends to collect as a body in the lower end thereof; withdrawing steam from said steam chamber at a rate sufficient to meet the steam demand; condensing at least a part of the steam thus withdrawn and returning the resulting condensate to a second chamber; withdrawing water at a given maximum level from said steam chamber at a rate sufficient to prevent the rise of said level above said maximum level while precluding the escape of steam at said level and moving said water in heat-transferring relation with said condensate; and withdrawing water from said second tank and forcing same into said elongated heating zone.

12. A method of generating steam, which includes the steps of: moving under pressure along an elongated heating zone a stream of water in excess of that required to meet the steam demand; heating said stream and expanding same as a jet into an upper steam zone of a steam chamber in which the pressure is lower than in a portion of said elongated heating zone, while controlling the heat applied to said heating zone to superheat the water therein to such an extent that release into said steam zone will flash a portion of the superheated water into steam and form a jet containing both water droplets and steam to facilitate ebullition, said water droplets dropping to the lower part of said steam chamber to form a body of water; withdrawing steam from said steam zone to meet the steam demand; determining the uppermost position of the surface of said body of water by withdrawing through a port communicating with said steam chamber at the desired uppermost position all excess water entering said chamber; and returning this excess water to said elongated heating zone along with sufficient make-up water to meet the steam demand.

13. A method of generating steam, which includes the steps of: moving under pressure along an elongated heating zone a stream of water; heating this water to such an extent that a portion but not all thereof is vaporized, while maintaining such velocity in said elongated heating zone as will prevent separation of the steam from the water with consequent steam pockets thereby forming a heated stream comprising mixed steam and water; discharging this heated stream into an upper steam zone of a steam chamber while restricting this discharge to form an expanding jet in said steam zone and comprising both small water droplets and steam to facilitate ebullition, the water droplets dropping to the lower part of said steam chamber to form a body of water; determining the uppermost position of the surface of said body of water by withdrawing from said steam chamber at the desired uppermost position of said surface all excess water entering this chamber; and returning this excess water to said elongated heating zone.

14. In combination in a device for generating steam: walls defining an elongated heating zone;

pump means providing an intake and a discharge for delivering a stream of water thereto in amount greater than that required to meet the steam demand; heating means for said elongated heating zone; a container providing a steam chamber containing steam in its upper end and a body of water in its lower end; means for delivering the heated stream from said elongated heating zone into said steam chamber for separation of steam and water; a tank defining a second chamber; a conduit for delivering water from said container to said second chamber; means connected in said conduit for allowing the flow of water from said container to said second chamber while precluding the escape of steam through said conduit; means for supplying make-up water to said second chamber; and means for conducting water from said second chamber to said intake of said pump means.

15. In combination in a device for generating steam: means providing a heating zone; a pump means for delivering a stream of water to said heating zone at a rate in excess of that required to meet the steam demand; a container providing a steam chamber; means for delivering a heated stream from said heating zone to said steam chamber; means for supplying heat to said heating zone in amount insufficient to vaporize all of the water supplied thereto but sufficient to maintain steam in the upper end of said steam chamber, the excess water collecting as a body in the lower end thereof; a tank providing a second chamber; pipe means communicating with said steam chamber and providing an entry portion disposed horizontally opposite the desired uppermost position of the surface of said body of water, said pipe means communicating with said second chamber whereby water may move from said steam chamber to said second chamber when said surface rises; means connected in said pipe means for allowing the flow of water from said steam chamber to said second chamber while precluding the escape of steam through said pipe means; means for withdrawing steam from the upper end of said steam chamber; means for supplying make-up water to said second chamber; and means communicating between said second chamber and said pump means for delivering water to said pump means for subsequent circulation through said heating zone.

16. In combination in a device for generating steam: means providing a heating zone; a pump means for delivering a stream of water to said heating zone at a rate in excess of that required to meet the steam demand; a container providing a steam chamber; means for delivering a heated stream from said heating zone to said steam chamber; means for supplying heat to said heating zone in amount insufficient to vaporize all of the water supplied thereto but sufficient to maintain steam in the upper end of said steam chamber, the excess water collecting as a body in the lower end thereof; a tank providing a second chamber; pipe means communicating with said steam chamber and providing an entry portion disposed horizontally opposite the desired uppermost position of the surface of said body of water, said pipe means communicating with said second chamber whereby water may move from said steam chamber to said second chamber when said surface rises; automatic means connected in said pipe means for controlling the flow of water through said pipe means while precluding the escape of steam through said pipe means; means for withdrawing steam from the upper end of said

steam chamber and moving same to a load acting to condense at least a portion of the steam; means for delivering the resulting condensate to said second chamber; and means communicating between said second chamber and said pump means for delivering water to said pump means for subsequent circulation through said heating zone.

17. In combination in a device for producing steam: a heater providing a heating zone; a container providing a steam chamber containing steam in its upper end and a body of water in its lower end; means for withdrawing steam from the upper end of said steam chamber; means for delivering a heated stream from said heating zone to said steam chamber; a pipe means communicating with said steam chamber and providing an entry portion disposed horizontally opposite the desired uppermost position of the surface of said body of water, whereby water will be withdrawn from said steam chamber when said surface rises to a position adjacent said entry portion; a steam trap communicating with said pipe means to prevent the passage of steam therethrough should said surface drop to a position below said entry portion; pump means for delivering to said heating zone the water discharged through said steam trap; and means for supplying make-up water to said heating zone.

18. In combination in a device for producing steam: a heater providing a heating zone; a container providing a steam chamber containing steam in its upper end and a body of water in its lower end; means for withdrawing steam from the upper end of said steam chamber; means for delivering a heated stream from said heating zone to said steam chamber; a pipe means communicating with said steam chamber and providing an entry portion disposed horizontally opposite the desired uppermost position of the surface of said body of water whereby water will be withdrawn from said steam chamber when said surface rises to a position adjacent said entry portion; a tank communicating with said pipe means to receive any water withdrawn there-through from said steam chamber, said water collecting in said tank; means for supplying make-up water to said tank; a first pump for withdrawing water from said body of water in said steam chamber and returning same to said heating zone; and a second pump withdrawing water from said tank and returning same to said heating zone.

19. In combination in a device for producing steam: a heater providing a heating zone; a container providing a steam chamber containing steam in its upper end and a body of water in its lower end; means for withdrawing steam from the upper end of said steam chamber; means for delivering a heated stream from said heating zone to said steam chamber; a pipe means communicating with said steam chamber and providing an entry portion disposed horizontally opposite the desired uppermost position of the surface of said body of water whereby water will be withdrawn from said steam chamber when said surface rises to a position adjacent said entry portion; a tank communicating with said pipe means to receive any water withdrawn there-through from said steam chamber, said water collecting in said tank; a first pump for withdrawing water from said body of water in said steam chamber and returning same to said heating zone; a second pump withdrawing water from said tank and returning same to said heating

zone; means for supplying water to said tank; and means for controlling the amount of water thus supplied to said tank to maintain the amount of water therein substantially constant.

20. A combination as defined in claim 18 including a steam trap in said pipe means providing said entry portion for preventing flow of steam from said steam chamber to said tank while permitting discharge of water from said steam chamber to said tank.

21. In combination in a device for producing steam: a heater providing an elongated heating zone; a container providing a steam chamber containing steam at its upper end and a body of water in its lower end; means for delivering a heated stream from said heating zone to said steam chamber; means for withdrawing steam from the upper end of said steam chamber to meet a steam demand; means for withdrawing from said steam chamber any excess water tending to raise the surface of said body of water above a desired position; a tank providing a second chamber communicating with said last-named means to receive any water withdrawn from said steam chamber; means for supplying water to said tank; means for controlling the amount of water thus supplied to said tank to maintain a substantially constant amount of water therein; pump means for withdrawing water from said tank and moving same to said heating zone; and pressure responsive means associated with said steam chamber for stopping said pump means when a given pressure is attained in said steam chamber.

22. In combination in a device for producing steam: walls providing an elongated heating zone; pump means for delivering to one end of said heating zone an amount of water in excess of that required to meet the steam demand; heating means for progressively heating the stream of water moving through said heating zone; means responsive to the thermal conditions of the heated stream discharging from said heating zone and operatively connected to said heating means to automatically produce a stream containing both water and steam uniformly mixed, said elongated heating zone being of such size as to maintain uniformly dispersed in the stream any steam formed therein while precluding separation of this steam and formation of steam pockets; a container providing a steam chamber containing steam in its upper end and a body of water in its lower end; conduit means for conducting the heated stream containing steam and water to the upper end of said steam chamber; a restricted nozzle means for releasing said stream from said conduit into said steam chamber whereby an additional amount of water may flash into steam; means for withdrawing from said steam chamber all excess water tending to raise the surface of said body of water above a predetermined position; a tank containing a body of water; means for delivering any water thus withdrawn from said steam chamber to said tank in heat-transferring relationship with the water therein; and means communicating between said tank and said pump means whereby water is withdrawn from said tank and delivered to said end of said elongated heating zone.

23. In combination in a device for generating steam: means providing a heating zone; a pump means for delivering a stream of water to said heating zone at a rate in excess of that required to meet the steam demand; a container providing a steam chamber; means for delivering a

heated stream from said heating zone to said steam chamber; means for supplying heat to said heating zone in amount insufficient to vaporize all of the water supplied thereto but sufficient to maintain steam in the upper end of said steam chamber, the excess water collecting as a body in the lower end thereof; a tank providing a second chamber; pipe means communicating with said steam chamber and providing an entry portion disposed horizontally opposite the desired uppermost position of the surface of said body of water, said pipe means communicating with said second chamber whereby water may move from said steam chamber to said second chamber when said surface rises; and means for withdrawing steam from the upper end of said steam chamber, said pump means intaking both from said steam chamber and from said second chamber for withdrawing water from both chambers and delivering same to said heating zone.

24. A combination as defined in claim 23 including means for stopping the pumping action of said pump means when the pressure in said steam chamber rises above a predetermined point and for again starting the pumping action of said pump means when said pressure drops to a predetermined point, and including means for controlling the amount of heat delivered to said heating zone in response to variations in thermal conditions of the heated stream discharging therefrom to cut down the amount of heat supplied when the pumping action of said pump means stops.

25. A method as defined in claim 4 including the step of controlling the heat of said stream in response to changes in the thermal conditions of the stream near the end of said elongated heating zone to maintain these thermal conditions substantially constant.

26. A method as defined in claim 4 including the step of stopping the withdrawal of water from said chamber from at least one of said points, and consequently the return of this water to said elongated heating zone, when the pressure in said steam chamber rises above a predetermined value and again starting said withdrawal when the pressure in said steam chamber drops to a predetermined lower value.

27. In combination in a device for producing steam: a heater providing a heating zone; a container providing a steam chamber containing steam in its upper end and a body of water in its lower end; means for withdrawing steam from the upper end of said steam chamber; means for delivering a heated stream from said heating zone to said steam chamber; a tank; a pipe means communicating with said steam chamber and said tank and providing an entry portion disposed horizontally opposite the desired uppermost position of the surface of said body of water in said steam chamber, whereby water will be withdrawn from said steam chamber and discharged into said tank when said level rises to a level adjacent said entry portion; a steam trap communicating with said pipe means to prevent the passage of steam therethrough to said tank should said level drop to a position below said entry portion; means for adding make-up water to the water discharged through said steam trap and into said tank; and a pump for pumping said discharged water and make-up water from said tank to said heating zone.

28. The combination as set forth in claim 18 but including drive means for said first and second pumps; and means responsive to pressure

in said steam chamber for stopping said driving means when a given pressure is attained in said steam chamber and again starting said drive means upon a drop in pressure below said given pressure.

29. The combination as set forth in claim 18, but including means for continuously driving said first pump, and means responsive to pressure in said steam chamber for effecting intermittent operation of said second pump.

30. The combination as set forth in claim 18 but including separate means for driving said first and second pumps; and control means for said pumps arranged to operate one of said pumps continuously, and to intermittently operate the other of said pumps in accordance with pressure changes in said steam chamber.

31. The combination as set forth in claim 18, but including driving and control means comprising an electric circuit and a pressure responsive switch associated with said steam chamber, said control means being arranged to cause driving of said first pump continuously and driving of said second pump intermittently and in accordance with pressure changes in said steam chamber.

32. The combination as defined in claim 23 including means for stopping the pumping action of said pump means when the pressure in said steam chamber rises above a predetermined point and for again starting the pumping action of the pump means when said pressure drops to a predetermined point.

33. In combination, in a device for generating steam: walls defining an elongated heating zone; pump means providing an intake and a discharge for delivering a stream of water thereto in amount greater than that required to meet the steam demand; heating means for said elongated heating zone; a container providing a steam chamber containing steam in its upper end and a body of water in its lower end; means for delivering the heated stream from said elongated heating zone into said steam chamber for separation of steam and water, said means including a discharge means opening on the upper portion of said steam chamber whereby said stream discharges into a steam zone of said chamber at a position above said body of water, said discharge means further including a nozzle means acting to subdivide said stream whereby the resulting water droplets move downward in said steam zone and provide a large surface area available for ebullition; a tank defining a second chamber; a conduit for delivering water from said container to said second chamber; means for supplying make-up water to said second chamber; and means for conducting water from said second chamber to said intake of said pumping means.

34. In combination, in a device for generating steam: means providing a heating zone; a pump means for delivering a stream of water to said heating zone at a rate in excess of that required to meet the steam demand; a container providing a steam chamber; means for delivering a heated stream from said heating zone to said steam chamber; means for supplying heat to said heating zone in amount insufficient to vaporize all of the water supplied thereto but sufficient to maintain steam in the upper end of said steam chamber, the excess water collecting as a body in the lower end thereof; a tank providing a second chamber; pipe means communicating with said steam chamber and providing an entry

portion disposed horizontally opposite the desired uppermost position of the surface of said body of water, said pipe means communicating with said second chamber whereby water may move
 5 from said steam chamber to said second chamber when said surface rises; means for withdrawing steam from the upper end of said steam chamber; means for supplying make-up water to said second chamber; means communicating
 10 between said second chamber and said pump means for delivering water to said pump means for subsequent circulation through said heating zone; means for stopping the pumping action of said pump means when the pressure in said steam
 15 chamber rises above a predetermined point and for again starting the pumping action of said pump means when said pressure drops to a predetermined point; and means for controlling the amount of heat delivered to said heating zone in
 20 response to variations in thermal conditions of the heated stream discharging therefrom to cut down the amount of heat supplied when the pumping action of said pump means stops.

35. In combination, in a device for generating
 25 steam: means providing a heating zone; a pump means for delivering a stream of water to said heating zone at a rate in excess of that required to meet the steam demand; a container providing a steam chamber; means for delivering a heated

stream from said heating zone to said steam chamber; means for supplying heat to said heating zone in amount insufficient to vaporize all of the water supplied thereto but sufficient to maintain steam in the upper end of said steam
 5 chamber, the excess water collecting as a body in the lower end thereof; a tank providing a second chamber; pipe means communicating with said steam chamber and providing an entry portion disposed horizontally opposite the desired
 10 uppermost position of the surface of said body of water, said pipe means communicating with said second chamber whereby water may move from said steam chamber to said second chamber when said surface rises; means for withdraw-
 15 ing steam from the upper end of said steam chamber; means for supplying make-up water to said second chamber; means communicating between said second chamber and said pump means for delivering water to said pump means
 20 for subsequent circulation through said heating zone; means for stopping the pumping action of said pump means when the pressure in said steam chamber rises above a predetermined point and for again starting the pumping action of
 25 said pump means when said pressure drops to a predetermined point.

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