

Nov. 6, 1951

P. ARANT

2,574,368

STEAM GENERATING APPARATUS

Filed Aug. 28, 1943

3 Sheets-Sheet 1

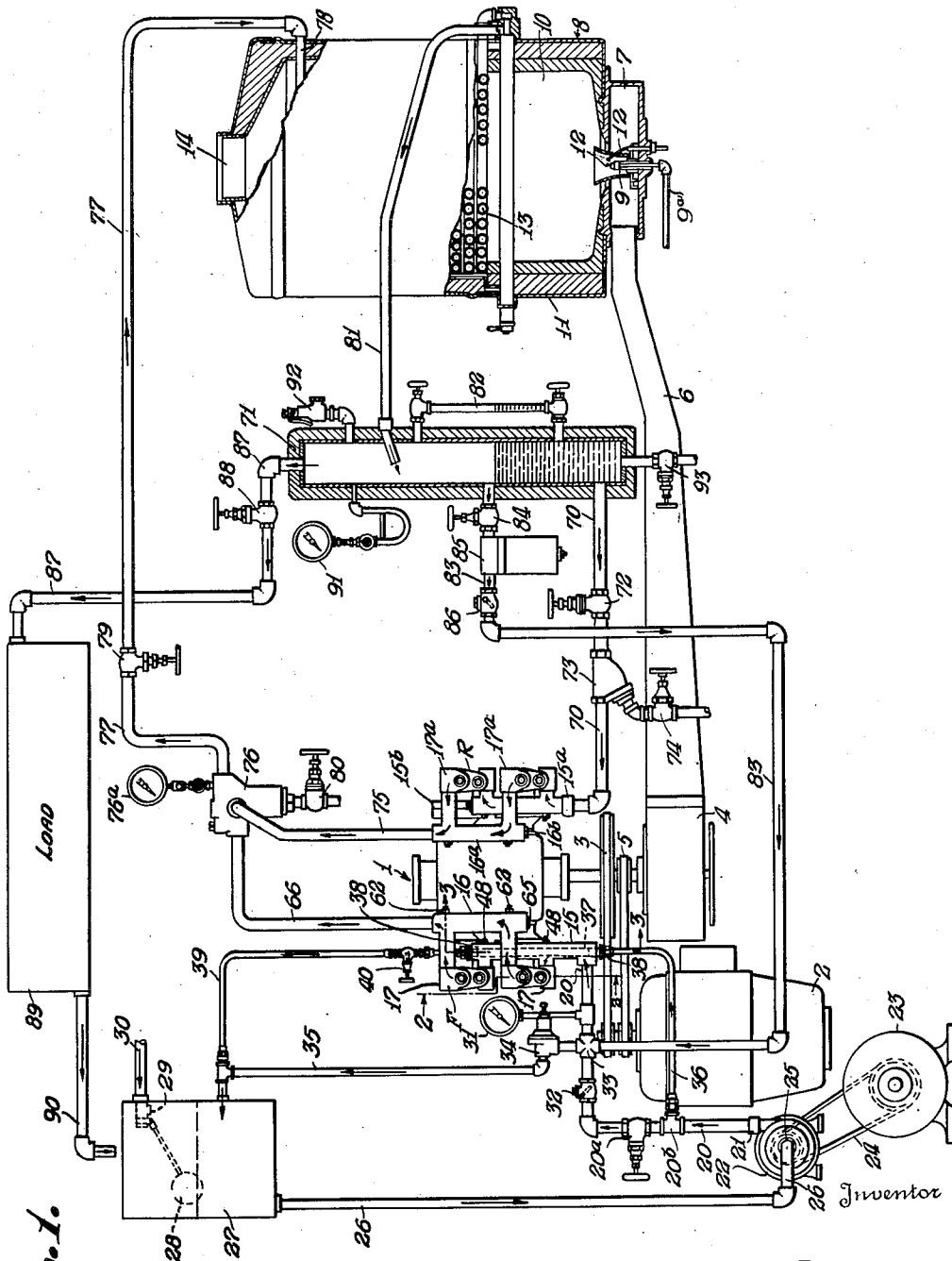


Fig. 1.

PERRY ARANT

By Baron + Thomas

Attorneys

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Fig. 2.

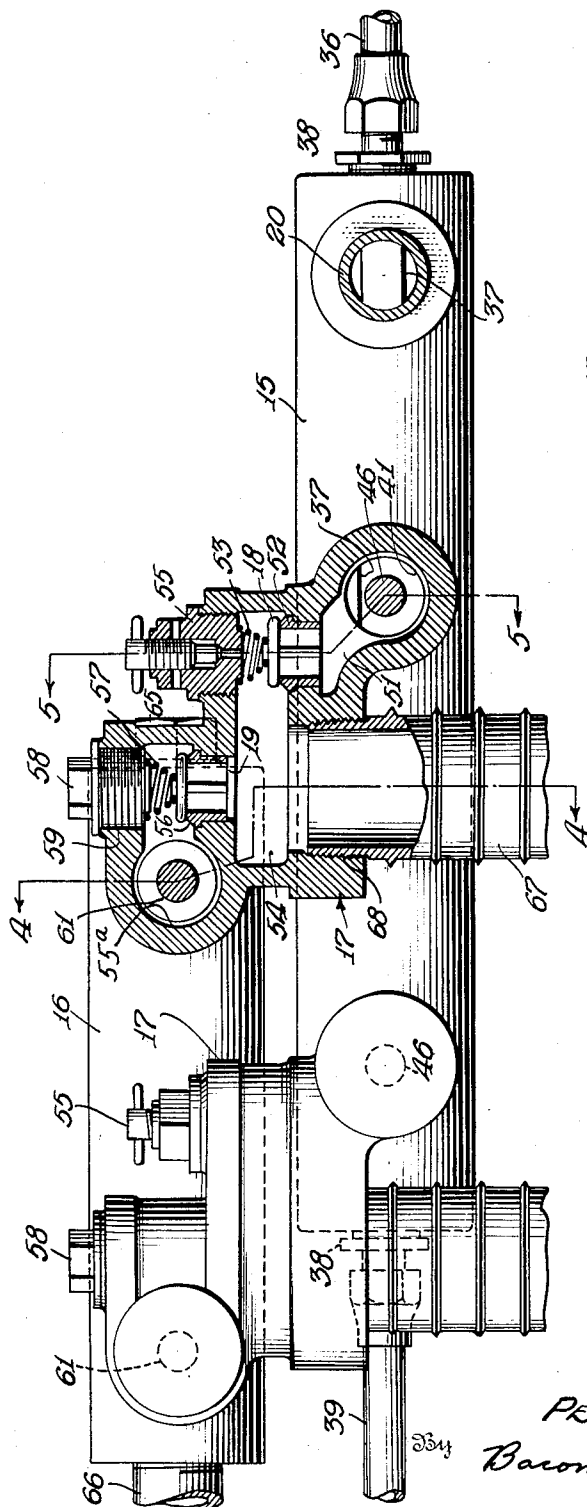
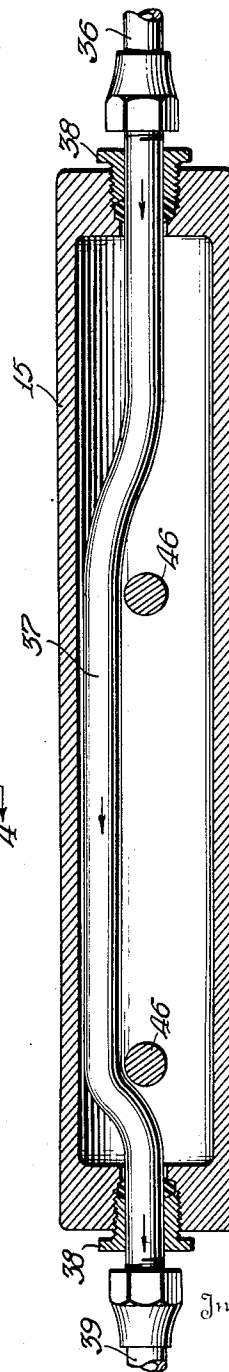


Fig. 3.

Inventor

PERRY ARANT
Bacon & Thomas
Attorneys

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P. ARANT

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Fig. 4.

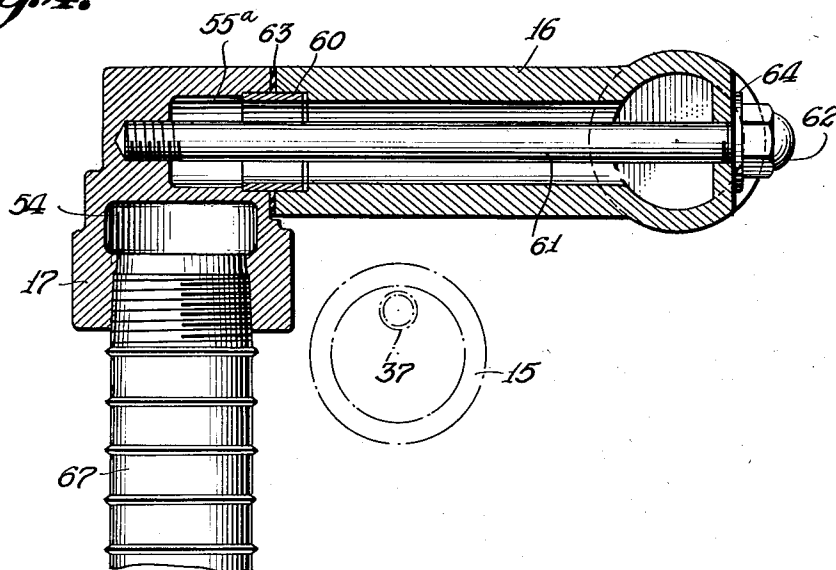
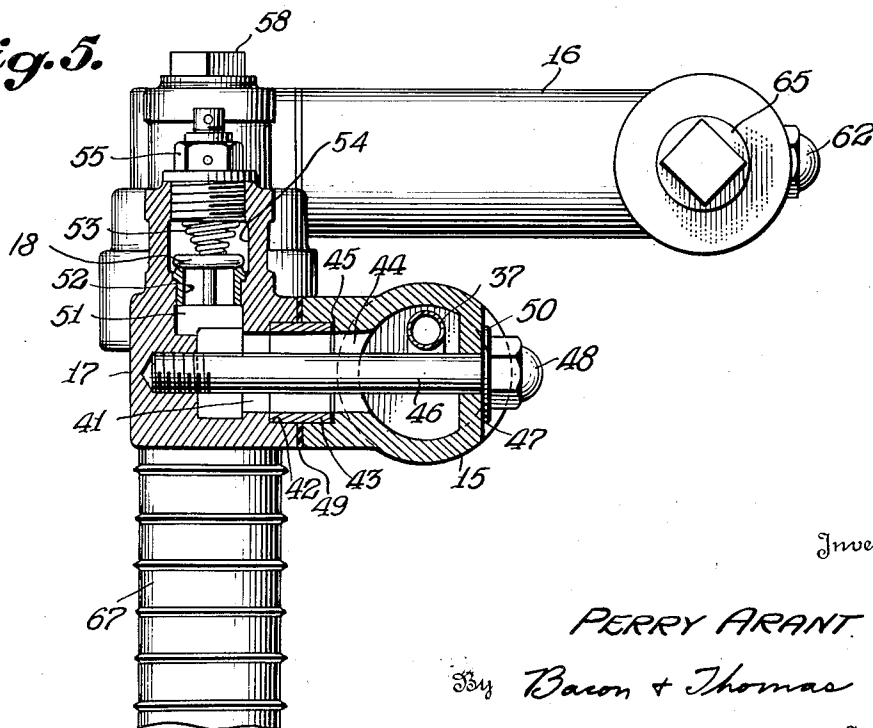


Fig. 5.



Inventor

PERRY ARANT

By Bacon & Thomas

Attorneys

UNITED STATES PATENT OFFICE

2,574,368

STEAM GENERATING APPARATUS

Perry Arant, Alhambra, Calif., assignor to Clayton Manufacturing Company, Alhambra, Calif.

Application August 28, 1943, Serial No. 500,413

22 Claims. (Cl. 122-411)

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The present invention relates to steam generating apparatus, and more particularly to a novel system of feed water supply and recirculation for use with a steam generating unit and steam separator, whereby a maximum of efficiency in operation can be attained.

The principal object of the invention is to provide a steam generating system in which heat losses are reduced to a minimum.

Another object of the invention is to eliminate the hot well heretofore used in steam generating apparatus to receive trapped-out liquid and accompanying vapor from a steam separator, and thereby avoid the escape of such vapor and the loss of its heat content to the atmosphere. In this connection, and aside from the heat loss, the escape of such vapor from the hot well is objectionable and undesirable in many installations.

One of the important features of the invention is that water is pumped to the heating coil at a rate in excess of the maximum steam generating capacity of the unit, whereby all overheating and possible burning out of the coil is avoided.

Another important feature of the invention is that the excess liquid above a given maximum level in the steam separator, instead of being trapped-off into a hot well, is conducted from the steam trap directly to the intake chamber or intake manifold of a feed pump and reintroduced into a heating coil or equivalent means.

Still another feature of the invention is the disposition of a check valve on the discharge side of the steam trap to prevent back-filling of the steam separator when the apparatus is initially started.

Another feature of the invention is the provision of means for condensing any steam that may be present in the intake manifold of the feed pump to prevent vapor-locking of said feed pump. Such feed pump is claimed in application Serial No. 746,189 filed on May 6, 1947, which is a division of the instant application.

A further feature of the invention is the use of a centrifugal pump serving in the dual capacity of a make-up water pump and a circulating pump for the heat exchange means associated with the intake manifold to prevent vapor-locking of the feed pump. A check valve associated with said centrifugal pump prevents the trapped-out liquid from the separator from backing up into said pump.

A further feature is the use of a relief valve on the outlet side of the steam trap set to open at a pressure lower than that normally main-

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tained in the steam separator so that a pressure differential exists upon the opposite side of said steam trap assuring satisfactory operation of said steam trap at all times.

A still further feature of the invention is that excess liquid is taken from the lower end of the steam separator and is recirculated through the heating coil and the amount of liquid trapped-out of the steam separator through the steam trap is thus materially reduced.

Other objects and features of the invention will be apparent from the following description, taken in conjunction with the accompanying drawings, in which:

Figure 1 diagrammatically illustrates a steam generating system embodying the principles and advantages of the present invention;

Figure 2 is an enlarged view, partly in elevation and partly in section, taken on the line 2-2 of Figure 1, and particularly illustrating the check valve arrangement associated with the intake chamber or manifold on the inlet side of the feed pump;

Figure 3 is a sectional view through the intake manifold, taken on the line 3-3 of Figure 1, particularly showing the arrangement of the heat exchange tube for condensing any vapor that may be present in the intake manifold to thereby prevent vapor-locking of the feed pump;

Figure 4 is a sectional view taken on the line 4-4 of Figure 2; and

Figure 5 is a sectional view taken on the line 5-5 of Figure 2.

Referring now to Fig. 1 of the drawings, the numeral 1 generally indicates a combined pump means which provides a feed water supply pump F and a recirculating pump R. The pump means 1 is driven by a motor 2 through a belt 3. The motor 2 also drives a blower 4 through a belt 5. The blower 4 is connected by a suitable conduit 6 with an air inlet chamber 7 of a steam generating unit generally designated by the numeral 8. The steam generating unit 8 comprises a suitable burner nozzle 9 to which fuel is supplied through a conduit 9^a. Fuel from the nozzle 9 is sprayed into a combustion chamber 10 contained within a housing 11 and is ignited by suitable electrode means 12. The housing 11 contains a heating coil or steam generating unit 13 of the pancake type through which the liquid to be heated is circulated. A flue 14 is provided at the upper end of the housing 11 for the escape of the products of combustion.

The feed pump F includes an intake feed manifold 15 and an outlet feed manifold 16 inter-

connected by identical housings 17 containing inlet check valves 18 and 19 (see Fig. 2), which housings will be described in greater detail hereinafter. The intake feed manifold 15 is connected by a pipe line 20 with the discharge opening 21 of a centrifugal or make-up pump 22. The centrifugal pump 22 is driven by a motor 23 through a belt 24. The inlet opening 25 of the centrifugal pump 22 is connected by a pipe 26 with a feed water tank 27 containing water at a temperature low enough so that no vapors arise therefrom. A predetermined minimum water level is maintained in the feed water tank 27 by a float mechanism 28 operatively associated with a float-controlled valve 29 and a water supply pipe 30.

The pipe line 20 has a pressure gauge 31 connected therein adjacent the intake feed manifold 15 and a one-way check valve 32 arranged between the centrifugal pump 22 and the pressure gauge 31. The check valve 32 is connected in the pipe 20 so as to allow flow therethrough only in a direction toward the intake feed manifold 15. A manually operated shut off valve 20^a is connected in the pipe line 20 on the inlet side of the check valve 32. A cross-fitting 33 is connected in the pipe line 20 between the pressure gauge 31 and the check valve 32. The upper opening of the cross-fitting 33 is connected with a pressure relief valve 34, the outlet of which valve is connected by a pipe 35 with the feed water tank 27. A conduit 36 has one end thereof connected with the stem of a pipe-T 20^b inserted in the pipe line 20 at a point between the centrifugal pump 22 and the manual valve 20^a and has its other end connected with heat exchange means in the form of a cooling tube 37 which extends through the intake feed manifold 15, as is best shown in Figs. 1 and 3. A leak-proof joint is provided between the outside of the tube 37 and the manifold 15 by suitable stuffing boxes 38 at each end of said manifold. The inlet end of the cooling or heat exchange tube 37 is connected to the conduit 36 and the outlet end of said tube is connected by a conduit 39 with the pipe 35 going to the feed water tank 27 from the relief valve 34. An adjustable needle valve 40 is connected in the conduit 39 to control the rate or volume of fluid that can pass through the heat exchange tube 37.

Referring now to Figs. 2 and 5, the check valve housings 17 are identical in construction and a description of one will therefore suffice for both. The housing 17 has an inlet opening 41 (Fig. 5) which is counterbored as indicated at 42 to receive a bushing 43. The intake feed manifold 15 has an outlet opening 44 which is counterbored at 45 to receive the bushing 43. The bushing 43 thus serves to align the housing 17 with the intake manifold 15. A stud 46 is threaded into the housing 17 and projects through an opening 47 in the manifold 15. A cap nut 48 is mounted upon the outer end of the stud 46 and secures the housing and manifold together in assembled relation. Suitable sealing means 49 is interposed between the confronting faces of the housing 17 and manifold 15 to avoid leakage and a suitable gasket 50 is disposed between the cap nut 48 and the manifold 15.

The opening 41 in the housing 17 communicates with a passageway 51 (Fig. 2) controlled by the check valve 18 previously referred to. The check valve 18 is normally urged toward its seat 52 by a conical spring 53. The housing 17 is further provided with a chamber 54 and the

check valve 18 controls the flow of liquid from the passage 51 into the chamber 54. A bleeder valve 55 is mounted in the housing 17 directly above the check valve 18 and provides a means for venting air from the chamber 54 when the pump means 1 is first started.

The housing 17 is still further provided with an opening 55^a (Fig. 2) adapted to communicate with the chamber 54 when the check valve 19 is raised from its seat 56. A spring 57 normally tends to maintain the check valve 19 closed. A removable plug 58 is disposed in an opening 59 directly above the check valve 19. As will be apparent from Fig. 4, the opening 55^a communicates with the outlet feed manifold 16 and said manifold is aligned with the housing 17 by a bushing 60 similar to the bushing 43. A stud 61 is threaded into the housing 17 and a cap nut 62 on the outer end of the stud secures the manifold 16 to the housing 17. Suitable sealing means 63 is disposed between the confronting faces of the housing 17 and the manifold 16 and a suitable gasket 64 is disposed between the manifold 16 and the cap nut 62. One end of the outlet feed manifold 16 is closed by a plug 65 and its opposite end is connected to a pipe 66.

A standpipe 67 (Fig. 2) is threaded into an opening 68 in the housing 17 and communicates at its upper end directly with the chamber 54. Normally, the standpipe 67 is filled with water and provides a water column through which pulsations from the pump means 1 are transmitted to any liquid contained in the chamber 54. The pump means 1 may include any suitable elements, such as a diaphragm (not shown) for producing pulsations in the standpipe 67 to produce a pumping action.

It will be apparent from the description thus far, that the water introduced into the intake feed manifold 15 through the pipe 20 will enter the opening 41 in the housing 17 and flow into the passageway 51, the check valve 18 opening in response to the pressure of such liquid to admit the same into the chamber 54 between pulsations in the standpipe 67 and fill said chamber. Hence, upon the next pulsation imparted to the liquid column in the standpipe 67, a certain amount of the water will be displaced from the chamber 54 and forced past the check valve 18 into the opening 55^a from whence it will flow into the outlet feed manifold 16 and into the pipe 66.

The recirculating pump R. of the pump means 1 includes an intake recirculating manifold 15^a and an outlet recirculating manifold 16^a (Fig. 1). These manifolds are generally similar to the manifolds 15 and 16 previously described, except that the inlet recirculating manifold 15^a is not provided with a heat exchange tube and is closed at one end by a plug 15^b. The outlet recirculating manifold 16^a is closed at one end by a plug 16^b. The manifolds 15^a and 16^a are interconnected by housings 17^a similar to the housings 17 previously described and it will be understood that the housings 17^a contain check valves similar to the check valves 18 and 19 already described. It will also be understood that the housings 17^a have standpipes (not shown) which function like the standpipes 67 to provide a pumping action to effect recirculation of the excess liquid as will be described hereinafter.

The inlet recirculating manifold 15^a is connected by a pipe 70 with the lower end of a steam separator 71. A manually controlled valve 72 in the line 70 serves to cut off communication

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between the steam separator 71 and the recirculating pump R. A strainer 73 is connected in the pipe line 70 and serves to prevent the passage of any foreign matter from the steam separator 71 through the pipe 70 into the inlet recirculating manifold 15^a. A strainer cleanout valve 74 is connected to the strainer 73 as shown.

The outlet recirculating manifold 16^a is connected by a pipe 75 with a conventional mixing chamber 76. The pipe 66 from the outlet feed manifold 16 is also connected with the mixing chamber 76. The mixing chamber 76 is, in turn, connected by a pipe 77 to the inlet end 78 of the heating coil 13. A manually controlled shutoff valve 79 connected in the pipe 77 controls the flow of liquid to the heating coil 13. Hence, it will be clear that feed water supplied through the pipe 66 and recirculating water supplied through the pipe 75 will be brought together in the mixing chamber 76 and then delivered to the heating coil 13 through the pipe 77. A pressure gauge 76^a indicates the pressure on the line 77 going to the heating coil 13. A valve 80 is connected with the mixing chamber 76 for effecting blowing-down of the heating coil 13.

The outlet end of the heating coil 13 is connected by a pipe 81 (Fig. 1) with the steam separator 71, so that the heating coil discharges into the upper portion of said steam separator and any of the liquid not flashed into vapor in said steam separator collects in the bottom thereof, and the level of said liquid is indicated by a gauge glass 82. In order to prevent the liquid level in the steam separator 71 from rising above a predetermined height, one end of a pipe 83 is connected to said separator at a level corresponding to the maximum desired liquid level in the separator, and the other end of said pipe is conveniently connected with the lower opening of the cross-fitting 33. The pipe 83 has a manually operable shut-off valve 84 connected therein on the inlet side of a steam trap 85. A one-way check valve 86 is connected in the pipe 83 between the steam trap 85 and the cross-fitting 33. The check valve 86 is installed to allow flow in the pipe 83 only in a direction away from the steam trap 85.

Steam may be taken from the upper end of the steam separator 71 through a pipe line 87 containing a manually operable shut-off valve 88. The pipe line 87 is connected with a load diagrammatically indicated at 89. A condensate return pipe 90 returns condensate from the load to the feed water tank 27. The steam separator 71 is also provided with a pressure gauge 91, a safety valve 92 and a blowoff or drain valve 93.

The operation of the apparatus from a cold start is as follows:

The motors 2 and 23 are preferably so arranged that both start simultaneously. Hence, the pump means 1, which handles both feed water and recirculating water, will start simultaneously with the centrifugal pump 22. The capacity of the pump means 1 exceeds the maximum steam generating capacity of the unit 8 so that an excess of water is supplied to the heating coil 13 and avoids all possibility of said heating coil burning out, and the capacity of the make-up pump 22 greatly exceeds that of the feed side F of the pump means 1 so that water can be withdrawn through the pipe 26 from the feed water tank 27 at a rate greater than the said feed pump F can handle the same. Such

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water will be forced past the check valve 32 in the pipe line 20 and will enter the intake feed manifold 15 and passage 51 in the housing 17 from whence it will flow (between pulsations in the standpipe 67) past the spring-pressed inlet check valve 18 into the chamber 54. The pulsations will force this water past the check valve 19 into the outlet feed manifold 16, through the pipe 66 and into the mixing chamber 76. The water will then be conducted by the pipe 77 to the inlet end 78 of the heating coil 13. When the coil 13 is filled, water will be discharged through the pipe 81 into the steam separator 71, and the fact that the coil 13 is filled will be indicated by the rise of level of the water in the steam separator 71, as indicated by the gauge glass 82. Back-filling of the steam separator 71 is prevented at this time by the one-way check valve 86 in the pipe line 83, which is maintained closed by the pressure created by the centrifugal pump 22. Any water delivered to the steam separator 71 will be conducted through the pipe line 70 to the intake recirculating manifold 15^a and will be pumped through the housings 17^a into the outlet recirculating manifold 16^a from whence it will be conducted by the pipe 75 to the mixing chamber 76, as will be readily understood, so that both feed and recirculating water will now be supplied to the heating coil through the pipe 77. While such recirculation is occurring, the burner 9 is started and the coil 13 is heated.

Meanwhile, water will continue to be supplied by the feed pump F and will be withdrawn from the steam separator 71 and recirculated by the recirculating pump R until the liquid in the heating coil 13 is heated to a point where at least a portion of it will flash into steam when introduced into the steam separator 71. The gauge 91 will indicate the steam pressure in the separator 71. As the pressure increases in the steam separator and should the level of the liquid in said steam separator rise to a height above the connection of the pipe 83 therewith, the liquid will be trapped-out of said steam separator through the steam trap 85 and will pass through the pipe line 83 into the pipe 20 connected with the intake feed manifold 15. During this portion of the cycle, if the water discharged from the steam trap 85 is under a greater pressure than that developed by the centrifugal pump 22, the check valve 32 will close, preventing any back-surfing into said centrifugal pump. The centrifugal pump 22 will then "slip" to any extent necessary to compensate for the reduction in the volume of its discharge caused by complete or partial closing of the check valve 32.

Due to the steam vapor accompanying the water discharged through the steam trap 85 and delivered through the pipes 83 and 20 to the intake feed manifold 15, or to the flashing of the heated liquid as the result of a reduction of pressure, it is possible for some vapor to occasionally enter or to form in the intake feed manifold 15 and cause a vapor-lock at the inlet check valves 18. Ordinarily, the feed pump F would remain vapor-locked only until the steam condensed, but such delay is undesirable and could prove detrimental to the operation of the steam generating apparatus because the interruption of a continuous flow of water to the heating coil 13 would result in overheating and possible burning out of said coil. By circulating cooling water from the feed water tank 27 through the heat exchange tube 37 (by means of the centrifugal

pump 22 and conduits 35 and 39) any steam vapor introduced into or formed in the intake feed manifold 15 is immediately condensed and vapor-locking of the feed pump F is totally avoided. Incidentally, the heat absorbed by the liquid pumped through the heat-exchange tube 37 is not lost because said liquid is returned to the feed water tank 27.

The tendency for a vapor-lock to form as a result of "flashing" due to a pressure drop will be apparent when the fact is considered that heated liquid may be trapped back from the steam separator 71 at a pressure of about 100 lbs. and at a temperature of about 337° F. Even a slight pressure drop in the intake feed manifold 15 will permit some of this liquid to flash into steam. On the other hand, the water which is passed through the heat exchange tube 37 is taken from the feed water tank 27 which contains water at a relatively low temperature of about 175°, and this temperature is sufficient to condense any vapor in the manifold 15. As has been pointed out before, the discharge end of the heat exchange tube 37 is connected with the feed water tank 27 by the conduit 39 so that the centrifugal pump 22 in effect circulates the feed water through the heat exchange tube 37.

By way of contrast, no heat exchange tube is necessary in the intake recirculating manifold 15 because the liquid entering said manifold is subject to the pressure in the steam separator 71 and hence no pressure drop can occur in said manifold which would cause any flashing of the liquid into steam and vapor-lock the recirculating pump R.

As the steam pressure is built up in the steam separator 71 and the steam is withdrawn from the top of said steam separator to meet a given demand, the liquid level in said separator may drop below the level of the pipeline 83, in which event no water will be trapped back from the separator through the steam trap 85. This will result in a reduction in the pressure in the pipeline 83 on the outlet side of the steam trap 85 so that the pressure tending to close the check valve 32 becomes less and when this pressure is exceeded by the pressure developed by the centrifugal or make-up pump 22, the check valve 32 will open and the pump 22 will then resume supplying feed water from the tank 27 to the feed pump F.

The relief valve 34 is provided to prevent equalization of the pressure in the steam separator 71 with the pressure at the intake feed manifold 15. Otherwise, the steam trap 85 would be rendered ineffective. Accordingly, the relief valve 34 is adjusted to open at a pressure that will always insure a differential such as to permit the steam trap 85 to function and prevent the liquid level in the steam separator 71 from rising too high. Thus, the apparatus may be designed to maintain steam in the steam separator 71 at a pressure of say, about 100 lbs. per square inch, whereas the relief valve 34 may be set to open at a pressure of about 50 lbs. per sq. inch, thereby providing a pressure differential of about 50 lbs. per sq. inch which will insure satisfactory operation of the steam trap 85.

It will be apparent from the foregoing that none of the heat content of the liquid trapped out of the steam separator 71 is lost, because this liquid is immediately delivered to the intake feed manifold 15, where, if it is commingled with make-up water, it will heat such water, and such heat as is taken out of the trapped liquid and

out of the steam to condense the same is absorbed by the cooling water flowing through the heat exchange tube 37 and returned to the feed water tank 27. The water level in the feed water tank 27 is maintained by the float mechanism 28, as previously explained, and comparatively cold water is introduced into the said tank at about the same rate as the steam demand so that this cold water assures a temperature of not more than about 175° in said feed tank which temperature is too low to cause any vapors to rise from the surface thereof.

It is to be understood that a conventional pressure switch (not shown) may be connected with the steam separator 71 to automatically control the operation of the motor 2, which drives the feed and recirculating pump means 1, so that the pump means will be stopped when a predetermined maximum pressure is attained in the steam separator 71. However, the centrifugal pump 22 is preferably arranged so that it will operate continuously when the apparatus is in use, thereby assuring a supply of water to the feed pump F when the motor 1 is restored. It will also be understood that the supply of fuel to the burner nozzle 9 may be controlled or modulated in accordance with the steam demand by any suitable control means.

While a heating coil 13 has been shown as a means for heating the liquid, it will be understood that such heating coil is not critical and that the principles of the system are equally applicable to boilers of header and tube construction. It will also be apparent that the invention is not restricted to the particular form of heat exchange means associated with the feed pump to prevent vapor-locking thereof. Moreover, it will also be apparent that a separate feed pump and a separate recirculation pump, with a motor for driving each (not shown), may be used in lieu of the combined feed pump and recirculating pump and the single motor drive therefor presently shown; all without departing from the spirit of the invention or the scope of the annexed claims.

I claim:

1. Steam generating apparatus comprising: conduit means adapted to receive a liquid to be heated, said conduit means having an inlet and an outlet; means for heating said conduit means; a feed pump for pumping liquid into the inlet of said conduit means, said feed pump having an inlet; a steam separator connected with the outlet of said conduit means; a continuous pipe line having one end thereof connected with said steam separator at a predetermined maximum desired liquid level and the other end thereof connected with said feed pump for conducting heated liquid directly from said steam separator to said feed pump; and means independent of said pipe line and connected with said feed pump for cooling said feed pump inlet to prevent vapor locking of said feed pump.

2. Steam generating apparatus comprising: conduit means adapted to receive a liquid to be heated, said conduit means having an inlet and an outlet; means for heating said conduit means; a feed pump for pumping liquid into the inlet of said conduit means, said feed pump having an intake chamber; a steam separator connected with the outlet of said conduit means; a continuous pipe line connected with said steam separator having one end thereof communicating with said steam separator at a predetermined maximum desired liquid level and the other end thereof connected with said feed pump intake chamber;

a steam trap in said pipe line for passing heated liquid and accompanying vapor from said steam separator directly to said feed pump intake chamber; and means independent of said pipe line for cooling said intake chamber to condense any vapor that may be present therein and thus prevent vapor-locking of said feed pump.

3. Steam generating apparatus comprising: conduit means adapted to receive a liquid to be heated, said conduit means having an inlet and an outlet; means for heating said conduit means; a feed pump for pumping liquid into the inlet of said conduit means, said feed pump including an intake chamber and a spring-pressed inlet check valve in said intake chamber; a steam separator connected with the outlet of said conduit means; a continuous pipe line connected with said steam separator having one end thereof communicating with said separator at a predetermined maximum desired liquid level and the other end thereof connected with said feed pump intake chamber; and a steam trap in said pipe line for passing heated liquid and accompanying vapor through said pipe line from said steam separator directly to said feed pump; and means independent of said pipe line and connected with said intake chamber for cooling said intake chamber to prevent vapor-locking of said inlet check valve.

4. Steam generating apparatus comprising: conduit means adapted to receive a liquid to be heated, said conduit means having an inlet and an outlet; means for heating said conduit means; a feed pump for pumping liquid into the inlet of said conduit means, said feed pump including an intake manifold and a spring-pressed inlet check valve arranged in a passageway communicating with an outlet of said intake manifold; a steam separator connected with the outlet of said conduit means; a pipe line connected with said steam separator having one end thereof communicating with said steam separator at a predetermined maximum desired liquid level and the other end thereof connected with said feed pump intake manifold; a steam trap in said pipe line for passing heated liquid and accompanying vapor from said steam separator directly to said feed pump; and heat exchange means independent of said pipe line connected with and having at least a portion thereof disposed in said intake manifold for condensing any steam that may be present in said intake manifold and thereby prevent vapor-locking of said inlet check valve.

5. Steam generating apparatus comprising: a heating coil having an inlet end and a discharge end; means for heating said coil; feed pump means for pumping liquid into the inlet end of said heating coil, said feed pump means including an intake manifold and an inlet check valve controlling the flow from said manifold; a steam separator connected with the discharge end of said heating coil; a pipe connecting said steam separator with said feed pump means arranged to conduct liquid at a given level from said steam separator to said intake manifold; a steam trap connected in said pipe for passing heated liquid and accompanying vapor from said steam separator to said intake manifold; heat exchange means in said intake manifold for condensing any steam that may be present in said intake manifold and thereby prevent vapor-locking of said inlet check valve; means for supplying make-up water to said inlet manifold; and means for diverting a portion of said make-up

water and introducing the same into said heat exchange means.

6. A steam generating apparatus comprising: a heating coil having an inlet end and a discharge end; means for heating said coil; feed pump means for pumping liquid into the inlet end of said heating coil, said feed pump means including an intake manifold and a spring-pressed check valve arranged in a passageway communicating with an outlet of said intake manifold; a steam separator connected with the discharge end of said heating coil; a pipe connecting said steam separator with said inlet manifold; a steam trap connected in said pipe, said steam trap serving to pass heated, excess liquid above a given level from said steam separator to said intake manifold; a centrifugal pump for supplying make-up water to said intake manifold; a heat exchange tube in said intake manifold for condensing any steam that may be present in said intake manifold and thereby prevent vapor-locking of said inlet check valve; and a conduit for cooling liquid having one end connected with the discharge side of said centrifugal pump and its other end connected with one end of said heat exchange tube.

7. Steam generating apparatus comprising: conduit means adapted to receive a liquid to be heated, said conduit means having an inlet and an outlet; means for heating said conduit means; a feed pump for pumping liquid into the inlet of said conduit means, said feed pump including an intake chamber; a steam separator connected with the outlet of said conduit means; a pipe line having one end connected with said steam separator and having its other end communicating with said intake chamber; a steam trap connected in said pipe line for passing heated liquid and accompanying vapor from said steam separator to said intake chamber; a feed water tank; a second pump having inlet and discharge openings; a pipe line connecting said feed water tank with the inlet opening of said second pump; means for cooling said intake chamber to condense any vapor that may be present therein; a supply conduit having one end communicating with the discharge opening of said pump and its other end communicating with said heat exchange means; and a return conduit connecting said heat exchange means with said feed water tank, whereby the water from said feed water tank is circulated through said heat exchange means to prevent vapor-locking of said feed pump.

8. Steam generating apparatus comprising: conduit means adapted to receive a liquid to be heated, said conduit means having an inlet and an outlet; means for heating said conduit means; a feed pump for pumping liquid into the inlet of said conduit means, said feed pump including an intake manifold; a steam separator connected with the outlet of said conduit means; a pipe line connected with said steam separator having one end thereof communicating with said steam separator at a predetermined point above the bottom of said steam separator corresponding to the maximum desired liquid level to be maintained in said steam separator and having the other end thereof communicating with said intake manifold; a steam trap in said pipe line, said pipe line normally conducting liquid from said steam trap directly to said intake manifold; means independent of said pipe line for cooling said intake manifold to prevent vapor locking thereof; a one-way check valve in said

pipe line between said steam trap and said intake manifold arranged to allow flow only in a direction from said steam trap toward said intake manifold; and means for supplying liquid to said intake manifold of said feed pump, said check valve preventing back-filling of liquid from said intake manifold into said steam separator during the initial starting of the apparatus.

9. Steam generating apparatus comprising: conduit means adapted to receive a liquid to be heated, said conduit means having an inlet and an outlet; means for heating said conduit means; feed pump means for supplying liquid to the inlet of said conduit means; a steam separator connected with the outlet of said conduit means; a pipe line connecting said steam separator with said feed pump means; a centrifugal pump for pumping liquid to the intake of said feed pump means; and a one-way check valve between said centrifugal pump and said feed pump means arranged to allow flow only in a direction away from said centrifugal pump, whereby when the pressure of the liquid from said steam separator exceeds the pressure of said centrifugal pump, said check valve will remain closed and said centrifugal pump will slip.

10. Steam generating apparatus comprising: conduit means adapted to receive a liquid to be heated, said conduit means having an inlet and an outlet; means for heating said conduit means; a feed pump for pumping liquid into the inlet of said conduit means, said feed pump including an intake manifold; a steam separator connected with the outlet of said conduit means; a pipe line connected with said steam separator having one end thereof communicating with said steam separator at a predetermined point above the bottom of said steam separator corresponding to the maximum desired liquid level to be maintained in said steam separator and having the other end thereof communicating with said intake manifold; a steam trap in said pipe line for passing heated liquid and accompanying vapor from said separator to said intake manifold; a make-up pump for supplying liquid to said intake manifold; a check valve arranged between said make-up pump and said intake manifold, said check valve being arranged to be opened only when the pressure of the liquid trapped through said steam trap is lower than the pressure of the make-up liquid delivered to said intake manifold by said make-up pump.

11. Steam generating apparatus comprising: conduit means adapted to receive a liquid to be heated, said conduit means having an inlet and an outlet; means for heating said conduit means; feed pump means for supplying liquid to the inlet of said conduit means; a steam separator connected with the outlet of said conduit means; a pipe line connecting said steam separator with said feed pump means, said pipe line having its point of connection with said steam separator at a means adapted to receive a liquid to be heated, said conduit means having an inlet and an outlet; means for heating said conduit means; feed pump means for supplying liquid to the inlet of said conduit means; a steam separator connected with the outlet of said conduit means; a pipe line connecting said steam separator with said feed pump means, said pipe line having its point of connection with said steam separator at a given predetermined height to maintain a given maximum water level in said steam separator; a steam trap connected in said pipe line for trapping-out liquid from said steam separator to

said feed pump means; a centrifugal pump for pumping make-up liquid to the intake of said feed pump means; and a check valve arranged between said centrifugal pump and said feed pump means, whereby when the pressure of the liquid trapped through said steam trap exceeds the pressure developed by said centrifugal pump, said centrifugal pump will slip and said feed pump means will pump said trapped-out liquid into the inlet of said conduit means.

12. Steam generating apparatus comprising: conduit means adapted to receive a liquid to be heated, said conduit means having an inlet and an outlet; means for heating said conduit means; a feed pump for pumping liquid into the inlet of said conduit means, said feed pump including an intake manifold; a steam separator connected with the outlet of said conduit means; a pipe line connected with said steam separator having one end thereof communicating with said steam separator at a predetermined point above the bottom of said steam separator corresponding to the maximum desired liquid level to be maintained in said steam separator and having the other end thereof communicating with said intake manifold; a steam trap in said pipe line for passing heated liquid and accompanying vapor from said separator to said intake manifold; a one-way check valve in said pipe line between said steam trap and said intake manifold; a make-up pump connected with said pipe line for supplying make-up liquid to said intake manifold, said check valve being arranged to prevent back-filling of liquid into said steam separator during the initial starting of the apparatus; a second check valve adjacent said make-up pump, said second check valve being arranged to be opened during operation of the apparatus only when the pressure of the liquid trapped through said steam trap is lower than the pressure of the make-up liquid delivered by said make-up pump.

13. Steam generating apparatus as defined in claim 12, in which a relief valve is arranged between the two check valves, said relief valve being set to open at a pressure substantially less than that normally maintained in said steam separator, whereby a pressure differential is maintained on the opposite sides of said steam trap. conduit means adapted to receive a liquid to be heated, said conduit means having an inlet and an outlet; means for heating said conduit means; a feed pump for pumping liquid into the inlet of said conduit means, said feed pump including an intake manifold; a steam separator connected with the outlet of said conduit means; a pipe line connected with said steam separator having one end thereof communicating with said steam separator and having the other end thereof communicating with said intake manifold; a steam trap in said pipe line for passing heated liquid and accompanying vapor from said steam separator to said intake manifold; and a relief valve connected in said pipe line between said steam trap and said intake manifold, said relief valve being set to open at a pressure substantially less than that normally maintained in said steam separator, whereby a pressure differential is maintained on the opposite sides of said steam trap assuring satisfactory operation thereof.

15. Steam generating apparatus comprising: conduit means adapted to receive a liquid to be heated, said conduit means having an inlet and an outlet; means for heating said conduit means; a feed pump for pumping liquid into the inlet of

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said conduit means; a steam separator connected with the outlet of said conduit means; a pipe line connected with said steam separator having one end thereof communicating with said steam separator at a predetermined point above the bottom of said steam separator corresponding to the maximum desired liquid level to be maintained in said steam separator and having the other end thereof connected with said feed pump; a steam trap in said pipe line for passing heated liquid and accompanying vapor from said separator to said intake manifold; a one-way check valve in said pipe line between said steam trap and said intake manifold, said check valve being arranged to allow flow only in a direction from said steam trap toward said intake manifold; and a pressure relief valve connected in said pipe line, said pressure relief valve being arranged to open at a pressure lower than that normally maintained in said steam separator.

16. Steam generating apparatus comprising: conduit means adapted to receive a liquid to be heated, said conduit means having an inlet and an outlet; means for heating said conduit means; a feed pump for pumping liquid into the inlet of said conduit means, said feed pump including an intake manifold and a spring-pressed inlet check valve arranged in a passageway communicating with an outlet of said intake manifold; a steam separator connected with the outlet of said conduit means; a pipe line connected with said steam separator having one end thereof communicating with said steam separator at a predetermined level above the bottom of said steam separator and having the other end thereof communicating with said intake manifold; a steam trap in said pipe line for passing heated liquid and accompanying vapor from said steam separator to said intake manifold; a feed water tank; a make-up pump for pumping water from said tank and supplying the same as make-up water to said intake manifold, said make-up pump having inlet and discharge openings; a pipe line connecting said feed water tank with said inlet opening of said make-up pump; heat exchange means in said intake manifold for condensing any steam that may be present in said intake manifold and thereby prevent vapor-locking of said inlet check valve; a conduit having one end connected with said discharge opening of said make-up pump and its other end connected with one end of said heat exchange means; and a return conduit connecting the other end of said heat exchange means with said feed water tank.

17. Steam generating apparatus as defined in claim 16, in which a recirculating pump is connected with the lower end portion of the steam separator and with the inlet of the conduit means for recirculating the liquid in said steam separator through said conduit means.

18. Steam generating apparatus comprising: conduit means adapted to receive a liquid to be heated, said conduit means having an inlet and an outlet; means for heating said conduit means; a feed pump for pumping liquid into the inlet of said conduit means, said feed pump including an intake manifold; a feed water tank; a centrifugal pump having inlet and discharge openings; a pipe line connecting said feed water tank with the inlet opening of said centrifugal pump; a pipe line connecting the discharge opening of said centrifugal pump with said intake manifold; a one-way check valve in said pipe line arranged to allow flow only in a direction from said centrif-

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ugal pump toward said intake manifold; a steam separator connected with the outlet of said conduit means; a pipe line having one end connected with said steam separator at a predetermined height to maintain a given maximum water level in said steam separator and having its other end communicating with said intake manifold; a steam trap connected in said last-mentioned pipe for passing heated liquid and accompanying vapor from said steam separator to said intake manifold; a check valve in said last-mentioned pipe line between said steam trap and said intake manifold; a relief valve connected in said last-mentioned pipe line between said check valve and said intake manifold, said relief valve being set to open at a pressure substantially less than that normally maintained in said steam separator so that a pressure differential is maintained upon opposite sides of said steam trap; a heat exchange tube in said intake manifold; a conduit for conducting liquid from the discharge side of said centrifugal pump to one end of said heat exchange tube; a conduit connecting the other end of said heat exchange tube with said feed water tank; a needle valve connected in said last-mentioned conduit for controlling the rate of flow of cooling fluid through said heat exchange tube; means for maintaining a predetermined water level in said feed water tank; and a recirculating pump for pumping liquid from the lower end of said steam separator to the inlet of said conduit means.

19. Steam generating apparatus comprising: a steam generating system including conduit means adapted to receive a liquid to be heated and a sump for condensate from said system; a pump for pumping liquid into the inlet of said conduit means, said pump including an inlet check valve and an inlet chamber ahead of said check valve; a conduit connected with said system for returning liquid at steam forming temperature to the inlet chamber of said pump; a heat exchange tube extending into said inlet chamber for cooling the heated liquid returned thereto to thereby prevent vapor-locking of said inlet check valve; packing means around said heat exchange tube for preventing the escape of fluid from said inlet chamber; and means interconnecting said tube with said sump for circulating the sump liquid through said tube to effect said cooling.

20. Steam generating apparatus, comprising: a steam generating unit adapted to receive a liquid to be heated, said unit having an inlet and an outlet for the liquid to be heated; means for heating said unit; a feed pump having the outlet thereof connected with the inlet of said unit for pumping liquid into said unit at a rate in excess of the maximum steam generating capacity of said unit; a steam separator connected with the outlet of said unit; a conduit interconnecting said steam separator with the inlet of said feed pump for conducting excess heated liquid from said steam separator directly to the inlet of said feed pump; and means independent of said conduit connected with said feed pump inlet for passing a coolant therethrough to cool said feed pump inlet to prevent said excess heated liquid from causing vapor-locking of said feed pump.

21. Steam generating apparatus, comprising: a steam generating unit adapted to receive a liquid to be heated, said unit having an inlet and an outlet for the liquid to be heated; means for heating said unit; a feed pump having the outlet thereof connected with the inlet of said unit for

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pumping liquid into said unit at a rate in excess of the maximum steam generating capacity of said unit; a steam separator connected with the outlet of said unit; a conduit interconnecting said steam separator and said feed pump for conducting excess heated liquid from said steam separator directly to the inlet of said feed pump; a feed water tank connected with said feed pump; and means for withdrawing liquid from said feed water tank and delivering the same to said feed pump inlet to effect cooling of said excess heated liquid to prevent vapor-locking of said feed pump inlet.

22. Steam generating apparatus, comprising: a steam generator unit adapted to receive a liquid to be heated, said unit having an inlet and an outlet for the liquid to be heated; means for heating said unit; a feed pump having the outlet thereof connected with the inlet of said unit for pumping liquid into said unit; a steam separator connected with the outlet of said unit; conduit means interconnecting said steam separator and said feed pump for conducting heated liquid from said steam separator directly to the inlet of said

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feed pump; a feed water tank; and means including a pump for delivering water from said feed water tank to the inlet of said feed pump in heat transfer relation with said heated liquid for cooling said heated liquid sufficiently to preclude vapor-locking of said feed pump.

PERRY ARANT.

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