

Oct. 31, 1933.

R. C. ROE

1,932,485

STEAM PLANT

Filed Feb. 9, 1931

2 Sheets-Sheet 1

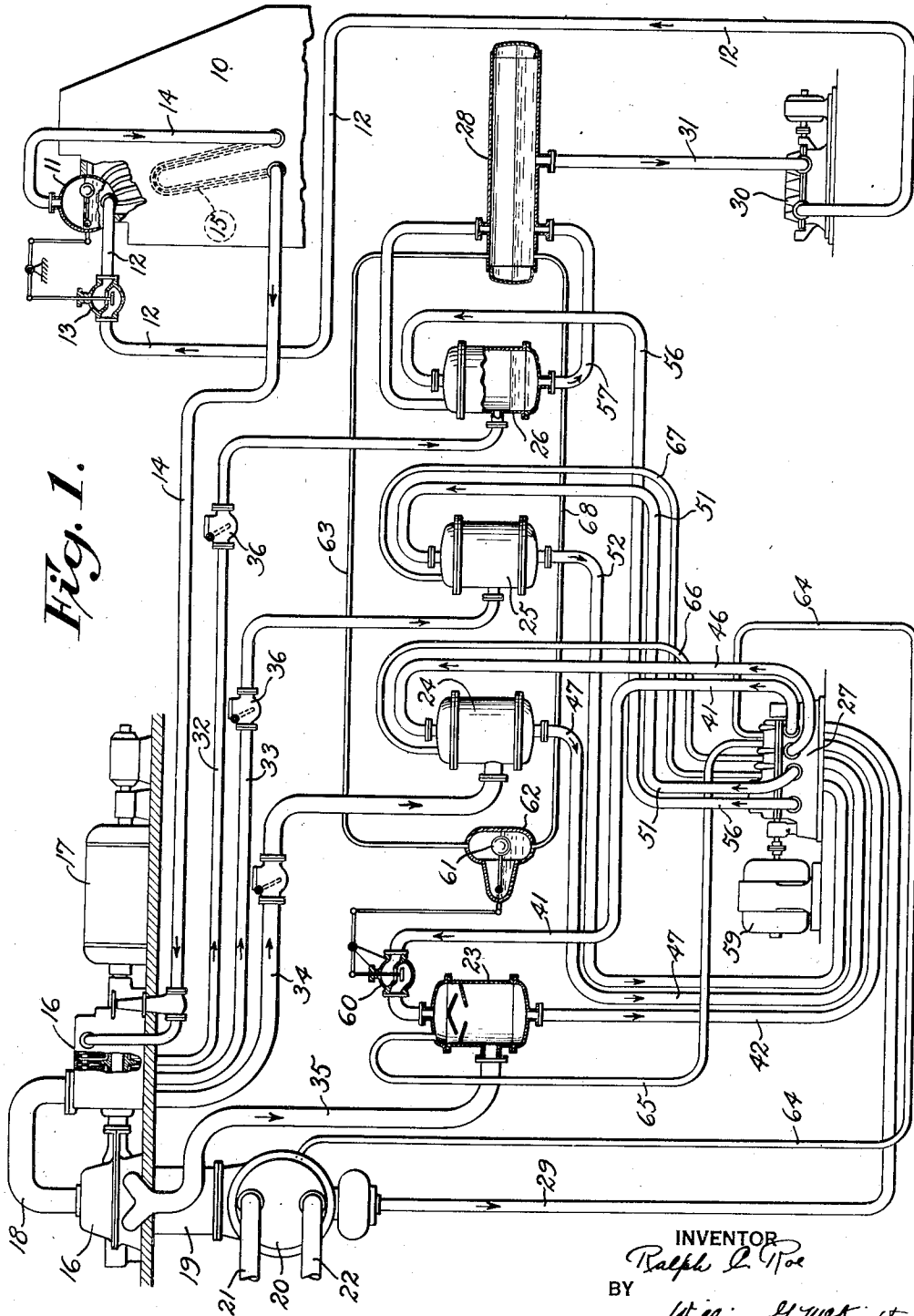


Fig. 1.

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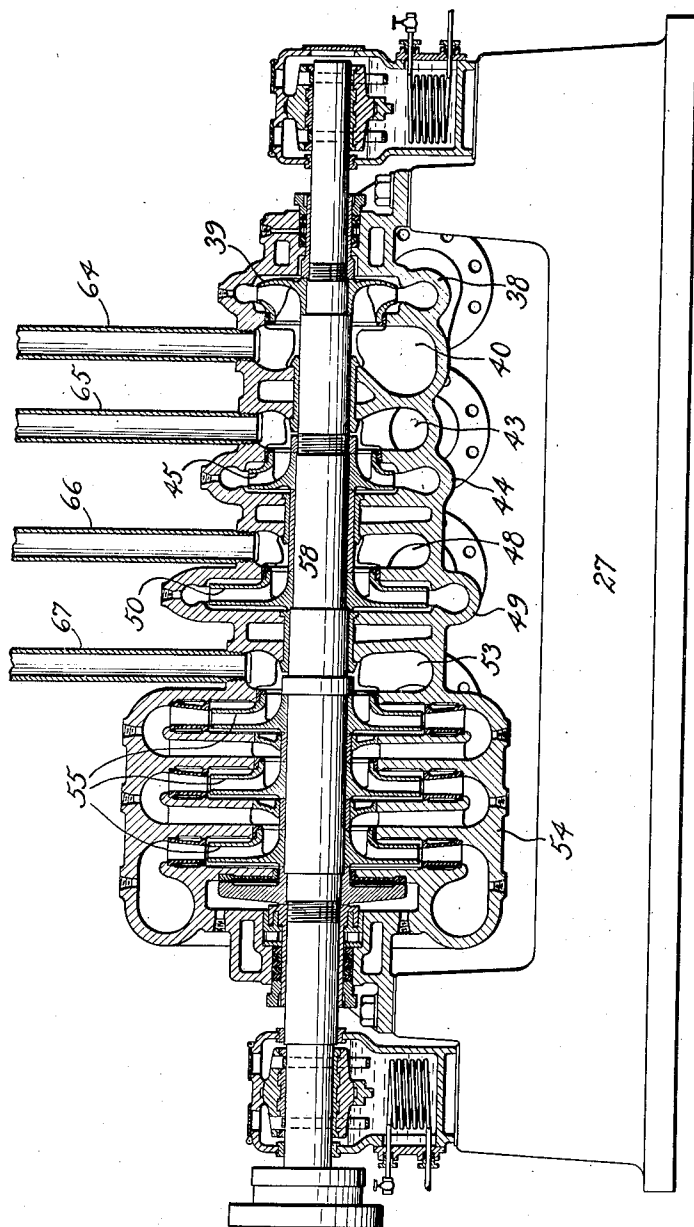


Fig. 2.

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1,932,485

STEAM PLANT

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Application February 9, 1931. Serial No. 514,404

15 Claims. (Cl. 60—94)

My invention relates to steam power plants and more particularly to such plants in which steam is bled from a plurality of points of different pressure of a prime mover and introduced into open feed water heaters in direct contact with feed water therein. In steam plants of this type, such as have been developed by me, it has been my aim to eliminate regulating mechanism so far as possible. To this end I have previously proposed to coordinate the flow of feed water to the amount of steam bled for different loads by making use of the characteristics of centrifugal pump mechanism and have concentrated, so far as possible, the control of feed water flow in a primary regulator, secondary regulation being obtained by means of water legs or valve regulation or both. The use of water legs avoids valves. In certain plants the heights of water legs make it desirable to use valves. In the present instance I avoid both any disadvantages inherent in high water legs and the use of secondary valve mechanism. This is accomplished by the use of a primary regulation to be hereinafter described and the use of vapor release connections between the centrifugal pump mechanism and other parts of the system.

The invention will be understood by reference to the accompanying drawings showing a preferred form thereof, which drawings constitute a part of this specification, and on which:

Fig. 1 is a more or less diagrammatic layout of a steam power plant employing the invention; and

Fig. 2 is a longitudinal cross-sectional view of centrifugal pump mechanism and vapor release connections in accordance with the invention.

In Fig. 1, reference character 10 designates a steam generating unit. This steam generating unit may be like any known construction and may include a plurality of boilers. The steam generating unit shown includes a steam and water drum 11 to which feed water is supplied by means of conduit 12. In conduit 12 is a valve 13 which is controlled in any of various known ways in response to liquid level in the drum 11 so that a constant level is maintained in the steam generating unit. Steam generated in the steam generating unit passes through conduit 14, and may pass through a superheater 15, to a turbine 16, or other prime mover. The prime mover may, for example, drive an electric generator 17. The turbine 16 comprises the usual rotor including blade wheels and guides. The prime mover may be divided into a number of sections connected by a conduit 18. Steam from the turbine

passes through connection 19 and into condenser 20, which is cooled by water passing through supply and discharge conduits 21 and 22.

The plant comprises a feed water system including feed water heaters 23, 24, 25, and 26. The feed water system also includes centrifugal pump mechanism designated generally at 27, connecting conduits between the feed water heaters and a control tank 28. Water is supplied from the condenser 20 to the feed water system by means of conduit 29. Water is conducted from the feed water system to the steam generating unit through the conduit 12, the water being pumped by means of a pump 30 which receives water from tank 28 through conduit 31.

The feed water heaters 23, 24, 25, and 26 are of the open direct contact type. That is, the steam and water in these heaters are in direct contact. This is as distinguished from surface heaters in which the steam to be condensed and the water to be heated are conducted in separate spaces which may be at different pressure.

A bleed or extraction conduit 32 connects a point of high pressure in the turbine 16 with the feed water heater 26. A bleed conduit 33 connects a point of lower pressure in the turbine 16 with feed water heater 25. A bleed conduit 34 connects a point of still lower pressure in the turbine 16 with feed water heater 24. A bleed or extraction conduit, connects a low pressure point of the turbine 16 with feed water heater 23. These bleed conduits may contain non-return valves diagrammatically indicated at 36 to prevent back flow of steam or water to the turbine. In normal operation, however, these conduits are unrestricted and are of such size or area as to permit maximum flow of steam at all times corresponding to maximum load on the turbine. The amount of steam flowing through these conduits is determined by the amount of water supplied to the respective feed water heaters since no more steam will flow than the water will condense. Putting it another way, the conduits are of such size that all the steam which the water can condense will flow through the bleed conduits since they are of large size and of unrestricted flow area. These conduits contain no regulating valves automatically operating in normal operation.

The centrifugal pump mechanism indicated generally at 27 and shown in detail in Fig. 2 includes a number of sections depending upon the number of feed water heaters. As stated,

feed water flows from the condenser through conduit 29 to the lowest section 38 of the pump mechanism, entering the inlet 40 thereof. Rotor 39 of this pump section pumps the water through conduit 41 and into the upper part of feed water heater 23. In feed water heater 23 the feed water supplied through conduit 41 comes into direct contact with and condenses steam which is drawn through conduit 35 and the resultant warmer water produced passes through conduit 42 and into the inlet chamber 43 of the second pump section 44 including the rotor 45. Pump section 44 pumps the water through conduit 46 and into feed water heater 24. The feed water here comes into direct contact with steam bled through conduit 34. The amount of feed water is increased by the amount of condensate produced by the condensing action of the water passing through conduit 46 on the steam passing through conduit 34. The water then passes through conduit 47 and into the inlet 48 of pump section 49, which includes the rotor 50. Pump section 49 pumps the water through conduit 51 and into the upper part of heater 25 where there is additional condensation of steam bled through conduit 33, the resultant heated water passing through conduit 52 to the inlet 53 of pump section 54 which includes rotors 55, there being three in this instance for the particular plant for which I have designed the pump illustrated. From pump section 54 the water is pumped through conduit 56 into the upper part of heater 26. Here there is a further condensation of steam bled through conduit 32 and a resultant warmer water passes through conduit 57 into tank 28. The connections of the water supply and discharge connections to the pump mechanism are made to the usual intermediate points.

The rotors of the pump mechanism are mounted on a shaft 58 which is driven at constant speed by a motor 59. One of the features of the present invention is constant speed operation of the centrifugal pump mechanism, thereby eliminating the necessity of variable speed control mechanism.

Interposed in conduit 41 is a valve 60 which controls the rate of flow in this conduit and which is adapted to close the conduit or to open the conduit to full capacity, or to restrict the effective area of the conduit to any intermediate degree. Valve 60 is controlled by a float 61 contained in a float chamber 62. Float chamber 62 is on a level with tank 28. The upper part of float chamber 62 is connected with tank 28 by a gas conduit 63. The lower part of float chamber 62 is connected to tank 28 by means of a liquid conduit 68. By this means, if the level is controlled in either tank 28 or float chamber 62, the same level will prevail in the two vessels. In effect, valve 60 is controlled by the liquid level in tank 28 and serves to maintain this liquid level constant. Since the restriction of conduit 41 determines the amount of water flowing through the feed water system, it will be seen that the primary control for flow of water through the feed water system is the amount of water in tank 28. On rise of water level in tank 28 and consequently in float chamber 62, valve 60 closes more or less. Conversely, on decrease of level in tank 28, valve 60 opens more or less.

Connected to the inlet chamber 40 of pump section 38 is a vapor release conduit 64 which is connected to the condenser 20. Connected to the inlet chamber 43 of pump section 44 is a vapor release conduit 65 which is connected to

feed water heater 23. Connected to the inlet chamber 48 of pump section 49 is a vapor release conduit 66 which is connected to the upper part of heater 24. Connected to the inlet chamber 53 of pump section 54 is a vapor release conduit 67 which is connected to the upper part of heater 25.

It will be seen from Fig. 2 that these conduits are of relatively large size and their diameter is approximately as great or nearly as great as the width of the inlet chambers at the points of connection of these conduits thereto. These conduits are of such area as to be able to provide substantially complete release of pressure in the inlet chambers. It will be noted that the pump mechanism is located below the feed water heaters and these vapor release conduits extend upwardly from the pump mechanism to their respective points of connection to the feed water system and the condenser.

In operation, the supply of steam to the turbine is controlled in known manner to suit the demand for power. The float valve or other regulating means of the boiler supplies water to the boiler as steam is generated so that the supply of feed water corresponds to the rate of steam generation. The withdrawal of feed water from tank 28 is consequently in accordance with the rate of steam supplied to the turbine. As the level in tank 28 is lowered, valve 60 in conduit 41 is opened and a greater quantity of feed water is pumped through the feed water system so that the quantity of feed water being pumped is in accordance with the demand for feed water and also in accordance with the demand for steam. As stated, the centrifugal pump mechanism 27 is driven at constant speed. Consequently, the amount of water passing through the pump rotors may be anything from full capacity to a small fraction thereof, depending upon the load on the turbine. The pump rotors are designed in accordance with the requirements for feed water to correspond to bled steam at different loads. In this connection, reference may be had to my copending application Serial No. 399,152, filed October 12th, 1929, Pat. No. 1,857,332. Pump section 38 is normally supplied with a sufficient quantity of water for satisfactory operation due to the fact that it is supplied from the condenser hot well or storage tank. Such pump sections may be so designed that they will not pump themselves dry. The conditions with respect to pump sections 44, 49, and 54, are quite different, however. Except when operating at maximum water flow, these sections are, so to speak, starved by the partial closing of the valve 60 and, unless the pump mechanism is properly designed and provision is made, these sections will pump themselves dry with resulting possible damage to the pumps and interference with proper operation or other difficulties which cannot be tolerated. In a pump of usual design, operating as do the pumps here involved, that is to say, receiving water on the suction side which has absorbed substantially all the live steam which it can absorb, and which is therefore close to the flashing point, and which will therefore flash into steam if a small amount of heat is added to it, difficulty is experienced because friction losses in the pump entrance cause heating of the water and, if in addition to this the pump is starved, along with the result that the level of the water in the suction leg is drawn down, thereby reducing the pressure on the suction side and consequently lowering the flash point, a considerable

amount of steam may be generated in the pump section, which steam may result in a cessation in the flow of water since the rotor or rotors which are in the steam pocket become practically useless. If, now, water continues to flow into the inlet chamber and a sufficient static head is built up, the steam pressure will eventually be overcome and the steam pocket forced on through the pump and the flow of water will be resumed. This, however, may require a higher hydrostatic column than is convenient for the elevational disposition of the parts of the plant system.

I overcome this difficulty by providing the conduits 65, 66, and 67, and by making the inlet chambers of the pump sections of large area. The vapor release connections 65, 66, and 67 are of relatively large area so as to relieve the steam pressure. By connecting the vapor connections from each pump section to the feed water heater supplying such section, I conserve heat and improve the efficiency of the system. By choosing the proper size of vapor release conduits, the necessary height of water leg may be reduced to almost any desired extent.

It will be seen that, with respect to each of the pump sections 44, 49, and 54, there is a pump suction chamber, a feed water heater of the direct contact type above the pump section, a downflow connection from the lower part of the feed water heater to a point in the suction chamber below the top thereof, and an upflow connection from the top of the suction chamber to the upper part of the feed water heater. Vent connections have previously been used on pumps, but these are usually small pipes of a fraction of an inch diameter, whereas the vapor release connections I have designed for a plant embodying this invention are of several inches diameter.

While the connection 64 may not be entirely necessary, I prefer to provide this connection also in order to insure release of steam pockets in the lowest pressure pump section. The conduits 65, 66, and 67 are of particular importance as secondary control members in connection with the flow of feed water through the feed water system which includes open direct contact heaters.

The operation of an individual pump section thus constructed and equipped with a vapor release conduit is as follows: The first action of the pump is to draw down the water in the suction conduit. When this water is drawn down low enough, a steam pocket is formed, which results in a momentary cessation of water flow. This is immediately followed by a building up of the suction head which in turn is immediately followed by the expulsion of the pocket through the vapor release connection, after which the flow is again established and the cycle repeated. I have carefully observed this action by means of a glass water column on the suction water leg of the pump and I have found that the action is quite rapid and varies with the amount of water being pumped. When the pump is operating at relatively low flows, as for instance, twenty-five per cent of its capacity, the fluctuations in the elevation in the water leg are quite extensive, varying through several feet with considerable rapidity and at regular intervals and, in one particular case which I have observed, at the rate of about thirty times per minute. As the amount of water being pumped increases, the variations become less extensive, finally disappearing entirely as the pump approaches full capacity.

However, at any load within the useful working range of the feed water system, the operating conditions are entirely satisfactory.

While I have described my invention in connection with a given plant, it will be understood that variations in structure and adaptability of the invention are possible within the scope of the invention.

What I claim is:

1. In a steam power plant, a steam generating unit, a prime mover, means to conduct steam from the steam generating unit to the prime mover, a first direct steam and water contact feed water heater, a second direct steam and water contact feed water heater, bleed conduits connecting the feed water heaters with points of different pressure in the prime mover, said bleed conduits being of normally constant effective flow area and of such area as to permit maximum flow of steam therethrough at all times during normal operation corresponding to maximum load on the prime mover, centrifugal pump mechanism having a rotor, an inlet chamber and an outlet chamber, means to conduct feed water from said first heater to said inlet chamber, means to conduct feed water from said outlet chamber to said second heater, a constantly open, unrestricted vapor release conduit connecting the upper part of said inlet chamber with said first heater, means to conduct fluid from said prime mover to said first heater and means to conduct fluid from said second heater to said steam generating unit.

2. In a steam power plant, a steam generating unit, a prime mover, means to conduct steam from the steam generating unit to the prime mover, a first direct steam and water contact feed water heater, a second direct steam and water contact feed water heater, bleed conduits connecting the feed water heaters with points of different pressure in the prime mover, said bleed conduits being of normally constant effective flow area and of such area as to permit maximum flow of steam therethrough at all times during normal operation corresponding to maximum load on the prime mover, centrifugal pump mechanism having a rotor, an inlet chamber and an outlet chamber, means to conduct feed water from said first heater to said inlet chamber, means to conduct feed water from said outlet chamber to said second heater, a constantly open, unrestricted vapor release conduit of relatively large cross-sectional area connecting the upper part of said inlet chamber with said first heater, means to conduct fluid from said prime mover to said first heater and means to conduct fluid from said second heater to said steam generating unit.

3. In a steam power plant, a steam generating unit, a prime mover, means to conduct steam from the steam generating unit to the prime mover, a first direct steam and water contact feed water heater, a second direct steam and water contact feed water heater, bleed conduits connecting the feed water heaters with points of different pressure in the prime mover, said bleed conduits being of normally constant effective flow area and of such area as to permit maximum flow of steam therethrough at all times during normal operation corresponding to maximum load on the prime mover, centrifugal pump mechanism having a rotor, an inlet chamber and an outlet chamber, means to rotate said centrifugal pump mechanism at constant speed, means to conduct feed water from said first heater to said inlet chamber, means to conduct feed water from said outlet chamber to said second heater, a constantly open, unre-

stricted vapor release conduit of relatively large area connecting the upper part of said inlet chamber with said first heater, means to conduct fluid from said turbine to said first heater and means to conduct fluid from said second heater to said steam generating unit.

4. In a steam plant, a plurality of direct contact feed water heaters, means to supply steam to said heaters, a plurality of centrifugal pump members receiving water from the heaters and constantly open, unrestricted vapor release conduits connecting each pump member with the feed water heater from which it receives water.

5. In a steam plant, a plurality of direct contact feed water heaters, means to supply steam to said heaters, a plurality of centrifugal pump members receiving water from the heaters, constantly open, unrestricted vapor release conduits connecting each pump member with the feed water heater from which it receives water, and means to rotate the pump member at constant speed.

6. In a steam power plant, a steam generating unit, a prime mover, means to conduct steam from the steam generating unit to the prime mover, a first direct steam and water contact feed water heater, a second direct steam and water contact feed water heater, bleed conduits connecting the feed water heaters with points of different pressure in the prime mover, said bleed conduits being of normally constant effective flow area and of such area as to permit maximum flow of steam therethrough at all times during normal operation corresponding to maximum load on the prime mover, centrifugal pump mechanism having a rotor, an inlet chamber and an outlet chamber, means to conduct feed water from said first heater to said inlet chamber, means to conduct feed water from said outlet chamber to said second heater, a vapor release conduit connecting the upper part of said inlet chamber with said first heater, means to conduct fluid from said prime mover to said first heater including a conduit and a valve therein, means to conduct fluid from said second heater to said steam generating unit and means to control said valve in accordance with differences in the rate of flow in the last-mentioned means.

7. In a steam power plant, a steam generating unit, a prime mover, means to conduct steam from said steam generating unit to said prime mover, a condenser, means to conduct steam from said prime mover to said condenser, a feed water system comprising a plurality of open direct contact feed water heaters, a tank, means to pump feed water successively from the condenser through the feed water heaters and into said tank and means responsive to water level variations in said tank for controlling the rate of flow of feed water, means to conduct feed water from said tank to the steam generating unit, and means to conduct steam to the feed water heaters from points of different pressure in the prime mover, said pumping means comprising a plurality of pump sections, and constantly open, unrestricted vapor release conduits from one or more of said pump sections to feed water heaters behind the respective pump sections in the line of flow of feed water.

8. In a steam power plant, a steam generating unit, a prime mover, means to conduct steam from said generating unit to said prime mover, a condenser, means to conduct steam from said prime mover to said condenser, a feed water system comprising a plurality of open direct contact

feed water heaters, a tank, means to pump feed water successively from the condenser through the feed water heaters and into said tank and means responsive to water level variations in said tank for controlling the rate of flow of feed water, means to conduct feed water from said tank to the steam generating unit, means to conduct steam to the feed water heaters from points of different pressure in the prime mover, said pumping means comprising a plurality of pump sections, constantly open, unrestricted vapor release conduits from one or more of said pump sections to feed water heaters behind the respective pump sections in the line of flow of feed water and means to drive the pumping means at constant speed.

9. In a steam plant, a steam generating unit, a prime mover, means to conduct steam from said steam generating unit to the prime mover, a first direct steam and water contact feed water heater, a second direct steam and water contact feed water heater, bleed conduits connecting the feed water heaters with points of different pressure in the prime mover, said bleed conduits being of normally constant effective flow area and of such area as to permit maximum flow of steam therethrough at all times during normal operation corresponding to maximum load on the prime mover, centrifugal pump mechanism having an impeller, an inlet chamber and an outlet chamber, means to conduct feed water from said first heater to said inlet chamber, means to conduct feed water from said outlet chamber to said second heater, a constantly open, unrestricted vapor release conduit connecting the upper part of said inlet chamber with a place of lower pressure in the plant and unaffected by said impeller, means to conduct fluid from said prime mover to said first heater and means to conduct fluid from said second heater to said steam generating unit.

10. In a steam plant, a steam generating unit, a prime mover, means to conduct steam from said steam generating unit to the prime mover, a first direct steam and water contact feed water heater, a second direct steam and water contact feed water heater, bleed conduits connecting the feed water heaters with points of different pressure in the prime mover, said bleed conduits being of normally constant effective flow area and of such area as to permit maximum flow of steam therethrough at all times during normal operation corresponding to maximum load on the prime mover, centrifugal pump mechanism having an impeller, an inlet chamber and an outlet chamber, means to rotate said impeller at constant speed, means to conduct feed water from said first heater to said inlet chamber, means to conduct feed water from said outlet chamber to said second heater, a constantly open, unrestricted vapor release conduit connecting the upper part of said inlet chamber with a place of lower pressure in the plant and unaffected by said impeller, means to conduct fluid from said prime mover to said first heater and means to conduct fluid from said second heater to said steam generating unit.

11. In a steam plant, a steam generating unit, a turbine, means to conduct steam from the steam generating unit to the turbine, a condenser supplied with steam from the turbine, a feed water heating system, means to conduct water from said condenser to said feed water heating system, and means to conduct water from said feed water heating system to said steam generating

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unit, said feed water system including a plurality of direct steam and water contact feed water heaters, a plurality of centrifugal pump members having impellers, connections between said pump members and said feed water heaters connected to break the continuity of water flow at the heaters, at least one of said pump members having an inlet chamber, an outlet chamber and an open, unrestricted vapor release conduit connecting the inlet chamber with a place in said system of less pressure than in said one of said pump members, and unaffected by the impeller thereof, means to drive said one of said pump members so that it is starved of water, said vapor release conduit being of such area as to completely release steam therefrom generated due to starving the pump member of water, and bleed conduits connecting the feed water heaters with points of different pressure in the turbine, said bleed conduits being of normally constant effective flow area and of such area as to permit maximum flow of steam therethrough at all times during normal operation corresponding to maximum load on the turbine.

12. In a steam plant, a steam generating unit, a turbine, means to conduct steam from the steam generating unit to the turbine, a condenser supplied with steam from the turbine, a feed water heating system, means to conduct water from said condenser to said feed water heating system, and means to conduct water from said feed water heating system to said steam generating unit, said feed water system including a plurality of direct steam and water contact feed water heaters, a plurality of centrifugal pump members having impellers, connections between said pump members and said feed water heaters connected to break the continuity of water flow at the heaters, at least one of said pump members having an inlet chamber, an outlet chamber and an open, unrestricted vapor release conduit connecting the inlet chamber with a place in said system of less pressure than in said one of said pump members and unaffected by the impeller thereof, means to drive said one of said pump members so that it is starved of water, said vapor release conduit being of such area as to completely release steam therefrom generated due to starving the pump member of water, bleed conduits connecting the feed water heaters with points of different pressure in the turbine, said bleed conduits being of normally constant effective flow area and of such area as to permit maximum flow of steam therethrough at all times during normal operation corresponding to maximum load on the turbine, and means to control flow of water into the feed water system in response to variations of water level in the feed water system.

13. In a vapor plant, a prime mover, a closed receptacle having direct contact of liquid with its vapor therein, unrestricted means to conduct vapor from said prime mover to said receptacle,

a centrifugal pump member situated below said receptacle and connected thereto to receive liquid therefrom, means to supply liquid in variable quantity to said receptacle, means separate from said receptacle for receiving liquid pumped through said pump member, and a constantly open, unrestricted vapor release conduit connecting said pump member with the vapor space of said receptacle and of such area as to completely release vapor from said pump member generated therein due to starving the pump member of liquid.

14. In a vapor plant, a prime mover, a closed receptacle having direct contact of liquid with its vapor therein, unrestricted means to conduct vapor from said prime mover to said receptacle, a centrifugal pump member situated below said receptacle and connected thereto to receive liquid therefrom, means to supply liquid in variable quantity to said receptacle, means separate from said receptacle for receiving liquid pumped through said pump member, a constantly open, unrestricted vapor release conduit connecting said pump member with the vapor space of said receptacle and of such area as to completely release vapor from said pump member generated therein due to starving the pump member of liquid, and means to drive said pump member at constant speed.

15. In a steam plant, a steam generating unit, a prime mover, means to conduct steam from the steam generating unit to the prime mover, a condenser supplied with steam from the prime mover, a feed water heating system, means to conduct water from said condenser to said feed water heating system, and means to conduct water from said feed water heating system to said steam generating unit, said feed water heating system including a direct steam and water contact feed water heater, a centrifugal pump member having an impeller connected to receive feed water from said heater and to deliver feed water to a point of higher pressure in the feed water heating system, said centrifugal pump member having an inlet chamber, an outlet chamber and an open, unrestricted vapor release conduit connecting the inlet chamber thereof with a place in said system of less pressure than in said pump member and unaffected by said impeller, means to drive said pump member so that it is starved of water, said vapor release conduit being of such area as to completely release steam therefrom generated due to starving the pump member of water, and a bleed conduit connecting said feed water heater with said prime mover, said bleed conduit being of normally constant effective flow area and of such area as to permit maximum flow of steam therethrough at all times during normal operation corresponding to maximum load on the prime mover.

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