

March 13, 1945.

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CLOSED FEED SYSTEM FOR STEAM POWER PLANTS

Filed Feb. 27, 1943

4 Sheets-Sheet 1

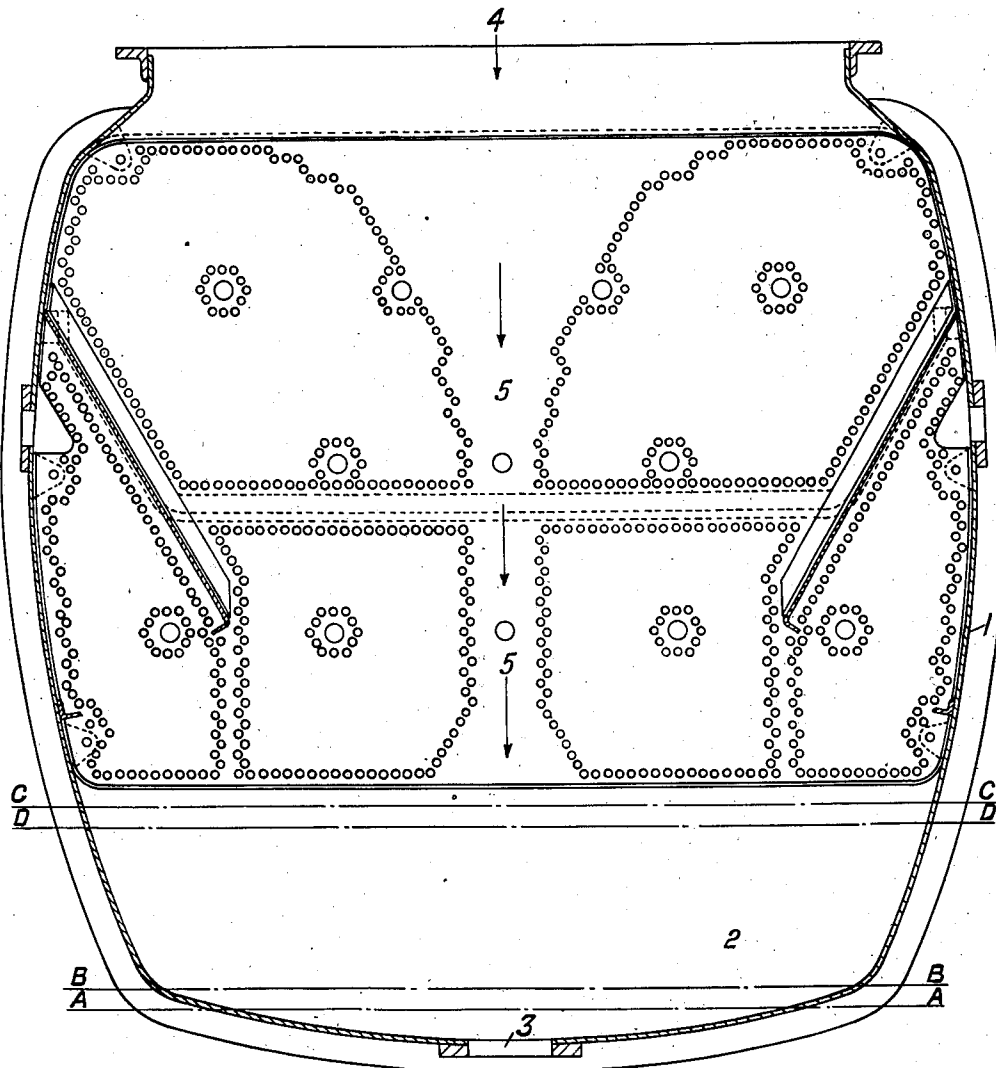


FIG. 1.

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4 Sheets-Sheet 2

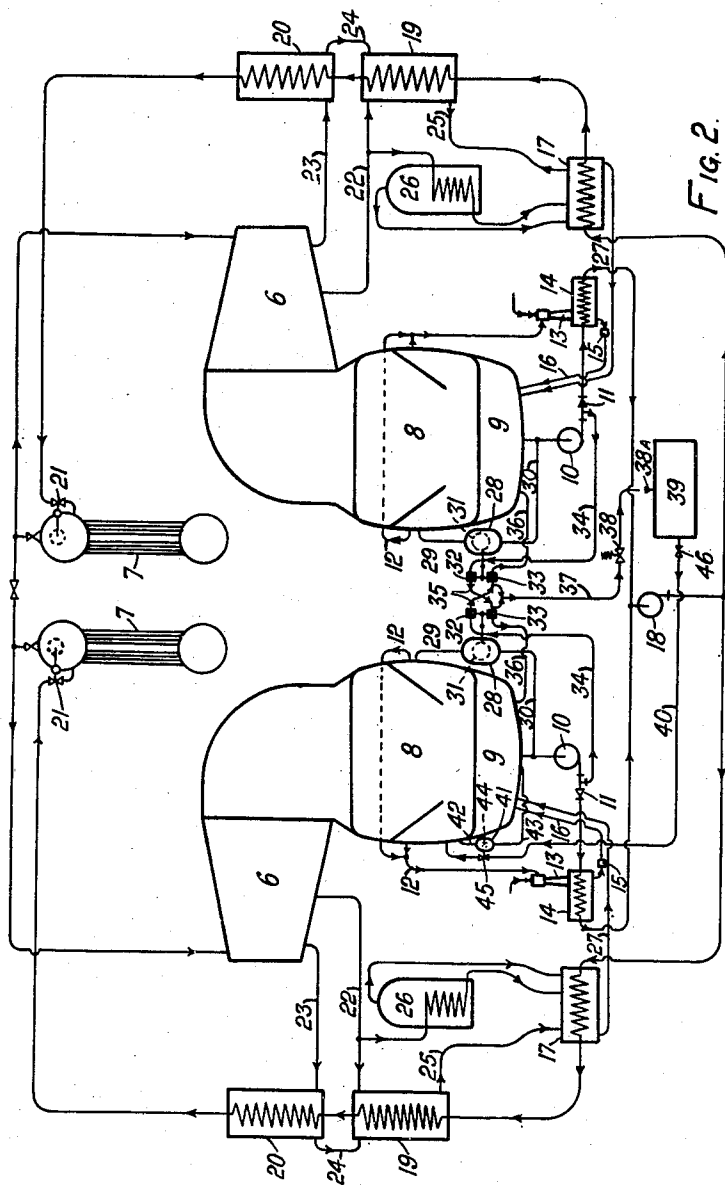


FIG. 2.

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4 Sheets-Sheet 3

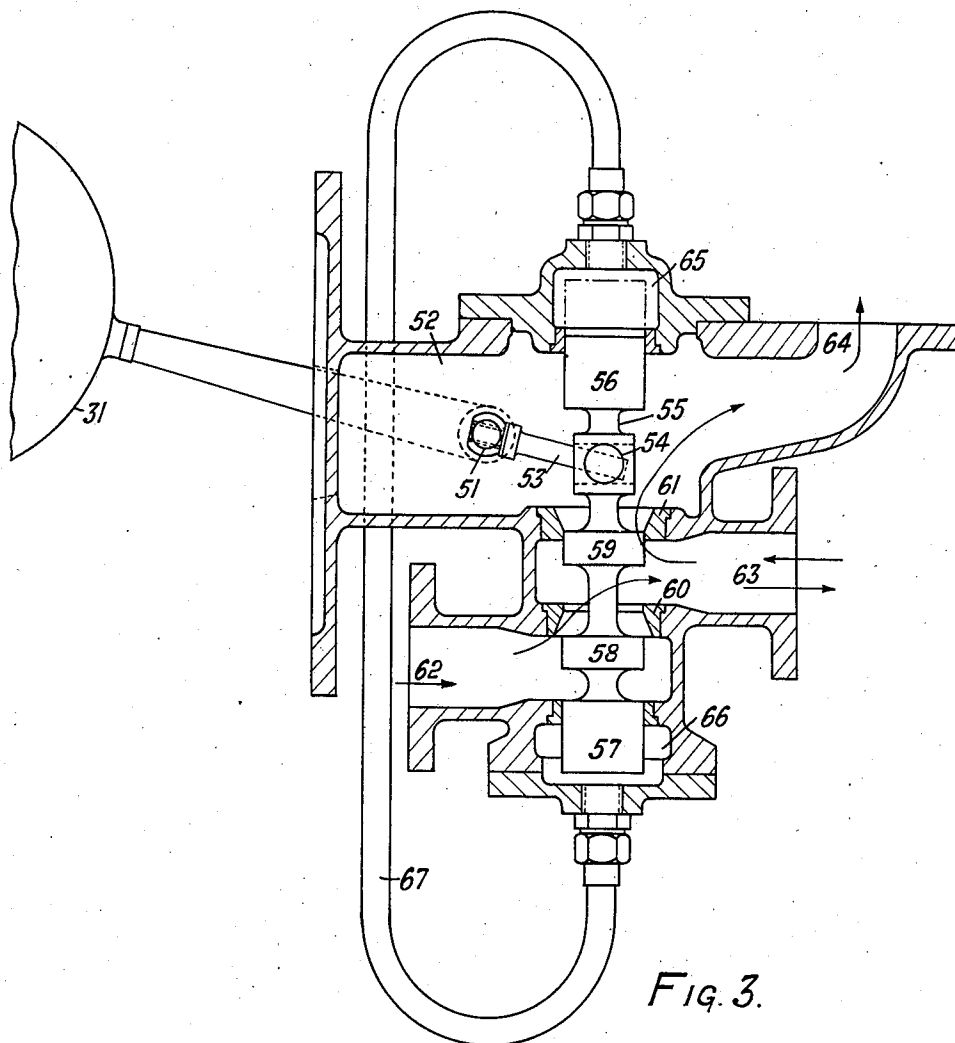


Fig. 3.

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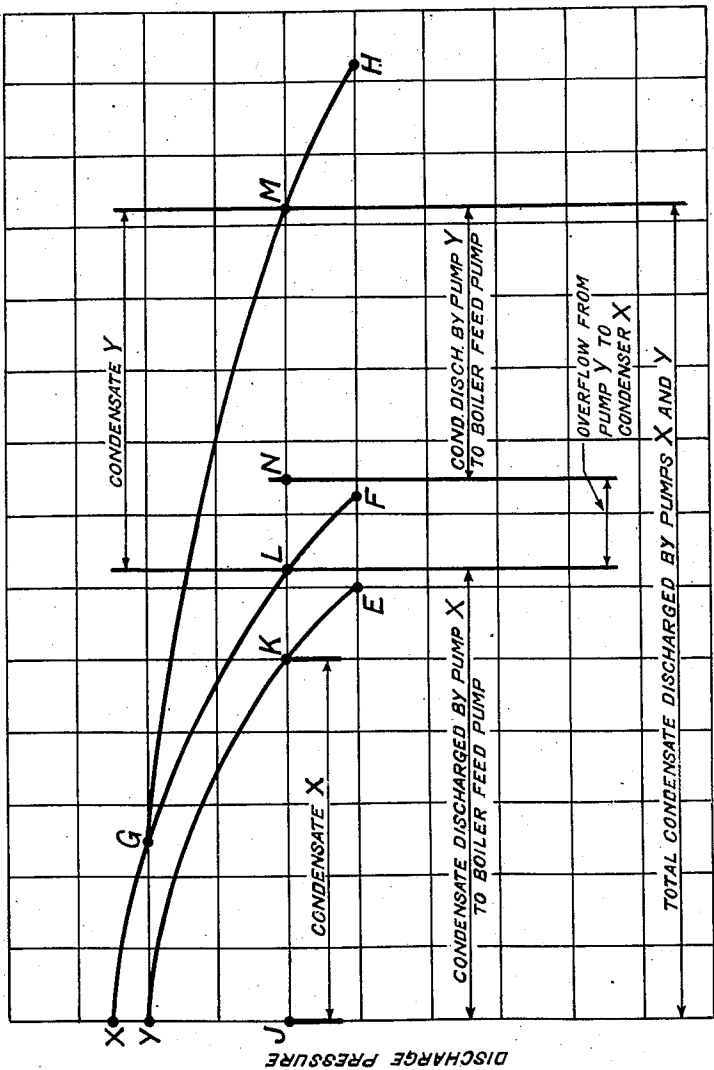
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4 Sheets-Sheet 4



QUANTITY OF FEED WATER
FIG. 4.

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CLOSED FEED SYSTEM FOR STEAM POWER PLANTS

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3 Claims. (Cl. 122-451)

The present invention relates to closed feed systems for steam power plants operating in parallel and each including a steam generator, a steam turbine, a steam condenser, and the appertaining feed water and steam connections.

The object of the invention is to provide a simplified arrangement whereby two or more closed feed systems can be operated stably and satisfactorily in parallel and whereby any external feed tanks can, if desired, be dispensed with.

According to the invention there is provided a well at, and in, or connected to, the bottom of each condenser, the water capacity of such well being sufficient to accommodate, between the minimum water level required by the condensate extraction pump and preferably the bottom tubes of the condenser, the volume of feed water returned from the boiler or boilers associated with and proportional to that condenser, there being associated with said condenser wells means whereby differences between the return of water to the respective condensers, variations in the operation of the respective condensers, their associated condensate extraction pumps, and differences in the characteristics of such pumps are automatically adjusted so as to ensure stable and satisfactory parallel operation of two or more closed feed systems.

The elimination of external feed tanks ensures that the feed water never leaves the closed feed system and has, therefore, no opportunity to absorb the component gases of atmospheric air the oxygen of which has a particularly deleterious effect on steel parts of the system. The continual circulation of the working fluid through the condenser ensures the optimum degree of removal of all non-condensable gases. Further advantages obtained by the omission of an external feed tank are saving in weight and space and the reduction of free water in the system to a minimum.

A further advantage I obtain is that the means for automatically controlling the system are smaller and lighter than used heretofore and function entirely automatically throughout any and all changes in loading of the system, thereby dispensing completely with any manual control of the feed water.

With a closed feed system in accordance with the invention a satisfactory distribution of feed water is ensured between the several condensers, irrespective of variations in the vacua in the condensers, differences in the condenser loadings and differences in the characteristics of the various condensate extraction pumps. Further, as

will be explained later, satisfactory parallel operation of the various condensate extraction pumps is ensured at all loads and under all conditions likely to obtain.

The invention will now be described with reference to the accompanying drawings in which:

Fig. 1 shows a section through a condenser and the well formed in the base of the condenser to illustrate the several operating water levels.

Fig. 2 shows diagrammatically the arrangement of a closed feed system in accordance with the invention for two steam power plants.

Fig. 3 shows in section one form of apparatus for automatically controlling the flow of feed water to and from a condenser in accordance with the invention.

Fig. 4 is a diagram illustrating the parallel operation of closed feed system units in accordance with the invention.

Referring to Fig. 1, the condenser shell 1 is provided with a well 2 the capacity of which is sufficient to accommodate the changes in water level which occur in the operation of a steam power plant with a closed feed system.

Steam generators in operation have a greater weight of water in the generator at no load than when steaming, due to the volume of the steam bubbles below the generator water level as such steam bubbles are formed and rise to the water level. This volume of steam bubbles increases with boiler load to a maximum at the maximum generator load with the consequence that the weight of water in the generator falls as the generator load is increased and the weight of water so displaced must be accommodated in the condenser well 2.

The condenser well is so proportioned that this volume of water is accommodated between the water level required for the satisfactory operation of the condensate extraction pump and a water level sufficiently below the bottom row of tubes in the condenser to permit a flow of steam across the water level to ensure the satisfactory deaeration of all condensate falling into the well. The well is provided with an outlet 3 from which the condensate extraction pump withdraws condensate from the condenser.

The level A—A indicates the minimum water level necessary to cause the flow of condensate through the outlet 3 and give a head sufficient to ensure the satisfactory operation of the condensate pump. To provide a margin to meet variations in operation, the normal water level with no load on the boiler is arranged at some suitably higher level such as B—B. As the

boiler load is increased, the water displaced in the boiler by the formation of steam bubbles is accommodated in the condenser well until, at full power, the water level rises to C—C which is sufficiently below the bottom row of tubes in the condenser to allow steam to pass from the steam inlet 4 of the condenser down the steam lane 5 to the surface of the water in the well 2, so that all condensate falling from the condenser tubes into the well must pass through such steam and, in doing so, be heated to boiling point so that it is at the maximum possible temperature before leaving the condenser, and all gases are driven out of the condensate before it passes into the feed system.

D—D shows the minimum water level which it is permissible to carry with full power on the boiler, the volume of water between the levels C—C and D—D being equal to the volume of water between the levels B—B and A—A. If the water level is being carried at D—D with full power on the boiler and the boiler load is reduced to zero, the water between the levels D—D and A—A will be discharged into the boiler to maintain the level in the boiler at the required height.

In Fig. 2 are shown two steam power plants, similar units in each plant being denoted by the same reference numerals. The steam turbine 6 receives steam from a steam generator or boiler 7 and exhausts into a condenser 8 which is provided with a well 9 below the bottom row of condenser tubes. A condensate extraction pump 10 withdraws condensate as required from the condenser well 9 and discharges the condensate into the feed system through the non-return valve 11. Air and other non-condensable gases are withdrawn from the condenser 8 through the pipes 12 by the air ejector 13 and discharged with the air ejector operating steam into the ejector condenser 14 wherein the steam is condensed and the heat transferred to the feed water which is discharged through the ejector condenser by the condensate extraction pump 10, the condensed ejector steam being drained into the condenser through a trap 15 and the pipe 16. After leaving the ejector condenser, the feed water passes to the suction of the boiler feed pump 18 which discharges the feed water through the drain cooler 17 and feed heaters 19 and 20 to the boiler feed regulator 21 which controls the flow of feed water into the boiler 7 as necessary to maintain the water level in the boiler to correspond to the boiler load requirements. The feed heaters 19 and 20 are supplied with heating steam bled from the main turbine 6 through pipes 22 and 23, respectively, the resultant drainage in the heater 20 being led into the heater 19 by the pipe 24 and the combined drainage from the heater 19 passing into the drain cooler 17 through the pipe 25. An evaporator 26 is supplied with bled steam from the main turbine 6 through the pipe 22 and such steam is used to evaporate sea water or other crude water in the evaporator, the vapour thus produced being condensed in the drain cooler 17 into which the evaporator coil drain is also led, the resultant drainage passing to the condenser 8 by the connection 27.

It will be seen that all steam used in the power plant and its associated feed heating and evaporating plant is condensed and drained into the condenser well so that the main circuit and the sub-circuits are all totally enclosed and at no time or place does the working fluid make any contact with the atmosphere.

The condenser well 9 has a water capacity which is greater than the difference in the weight of water in the boiler 7 between no boiler load and maximum boiler load, and such capacity is available between the minimum water level required by the condensate extraction pump and the bottom row of the tubes in the condenser.

When the two boilers 7 are being operated in parallel, which is the most convenient method of operation, it is necessary to ensure that the weight of water displaced from the boilers as the load increases from no load to full load shall be accommodated equally between the two condenser wells 9, and means must be provided to ensure such satisfactory distribution of the feed water between the two condensers irrespective of variations in the vacua in the condensers 8, the differences in loadings of the condensers and differences in the characteristics of the condensate extraction pumps 10. For this purpose, I provide for each condenser a closed feed control valve comprising an overflow and an inlet valve controlled by a float which is actuated from the water level in the condenser well 9. In Fig. 2 I have shown a separate chamber 28 connected to each condenser by pipes 29 and 30, so that the water level prevailing in the float chamber 28 is substantially the same at all times as the water level prevailing in the condenser well 9. The float 31 rises and falls in the float chamber 28 with the rise and fall of the water level and in so doing actuates the overflow valve 32 and the inlet valve 33. The float chamber is so placed relatively to the condenser well 9 that, on a change of water level upwards from a predetermined level, the overflow valve 32 is opened to effect the removal of water from the associated condenser by way of the condensate extraction pump 10, discharge line 34, overflow valve 32 and pipe 35, from where it can flow to the inlet valve 33 on the other condenser and pipe 36 into that condenser; or, in the event of the inlet valve being closed, the overflow is discharged by way of a pipe 37 and the spring-loaded valve 38 to a reserve feed tank 39 through an open funnel 38A. The level at which the overflow valve opens is preferably the level C—C in Fig. 1. The change of water level downwards from the predetermined water level, which is preferably C—C in Fig. 1, opens the inlet valve 33 to permit water to enter the associated condenser from the other condenser if the water level in that other condenser has risen above its predetermined operating water level.

It will be seen that, at full power, the water level in the condensers should be maintained between the levels D—D and C—C, and if there is any tendency for the water level in one condenser to rise above the level C—C, the overflow valve on that condenser is opened and water is discharged into the other condenser, until the level in that condenser reaches the level C—C, in which case that inlet valve is closed by the operation of the float and the rise in pressure due to the closing of that inlet valve will cause the pressure in the pipe line 37 to rise sufficiently to lift the spring-loaded valve 38 and permit any excess water not required in the condensers to pass into the reserve feed tank 39.

If the distilled water produced by the evaporating plant is in excess of requirements, the surplus will be discharged through the overflow valves, pipe 37, spring loaded valve 38, and open funnel 38A to the reserve feed tank 39. The make-up to the system should, in general, be

operated so that there is a slight continuous overflow to the reserve feed tank, and the open funnel enables the operating personnel to verify visually that an overflow is being obtained.

I may arrange for the reserve feed tank to be connected to one or more of the condensers, such connections to be provided with a valve which may be manually operated so as to pass water, when required, from the reserve feed tank into the condenser or condensers. I may arrange for such connection to be automatically operated by a float which may be arranged in a chamber separate from the condenser but connected thereto by pipes so that the level in the chamber is substantially the same as the level in the condenser.

On one of the condensers in Fig. 2, I have shown such a float chamber 41 connected to the condenser by pipes 42 and 43 and provided with a float 44 which operates a valve 45 to control the flow of water from the reserve feed tank 39, by way of the pipe 40, into the condenser.

The float-operated valve 45 may be so arranged that it opens whenever the water level falls below some predetermined level in the condenser well such as the level D—D, in which case water can be drawn from the reserve feed tank into the condenser when so desired.

The connection 40 may be provided with a manually operated isolating valve 46 which can be opened when it is desired to pass water from the reserve feed tank into the closed feed system.

The float-operated valve 45 or the manually operated valve 46 may be comparatively small in size and limited to, say, sufficient to provide an inflow of about 10 per cent of the maximum rate of feed flow in the closed circuit.

It will be understood that the overflow and inlet valves 32 and 33 comprising the means for controlling the closed feed circuit in accordance with the invention can be comparatively small since they are required to deal only with differences in the operation between the several condensers operating together and, for this purpose, the size of the valves can be limited to that which will pass, say, about 20 per cent of the maximum rate of feed flow through the closed circuit.

Fig. 3 shows one construction of a float-actuated closed feed circuit controller comprising an overflow valve and an inlet valve for the purposes previously described.

The float 31 is pivoted on a fulcrum 51 which is carried in the valve body 52, the said valve body being bolted to the condenser well so that the float is inside the condenser well and responds to changes in the level of water in the well.

An extension 53 of the float lever slides in a circular member 54 which passes transversely through the valve spindle 55 on which are provided pistons 56 and 57, which guide the valve spindle, and pistons 58 and 59 which engage with valve seats 60 and 61, respectively, to control the overflow and inlet of water from and to the condenser respectively.

The extraction pump discharge is connected to the branch 62 to permit overflow water to be passed through the valve seat 60 under the control of the overflow valve piston 58, water passing through the overflow valve, and leaving the valve body 52 by the branch 63. The branch 63 also permits inlet water to pass into the valve body 52 whence it can flow through the inlet

valve seat 61 under the control of the inlet valve piston 59 to the branch 64 whence the water can pass into the condenser with which the closed feed controller is associated.

To ensure that the leakages past the pistons 56 and 57 do not build up any pressure which is likely to disturb the hydraulic balance of the valve member, the chambers 65 and 66 associated with the pistons 56 and 57, respectively, are coupled by a balance pipe 67 so that the pressure in the two chambers is substantially the same.

The positions of the overflow piston 58 and the inlet piston 59 relatively to their seats 60 and 61, respectively, are such that, when the float is in the position corresponding to the top of its travel, the overflow valve is wide open and the inlet valve is closed. As the float falls to a predetermined level, the overflow piston 58 closes the opening through the seat 60 and further travel of the float in the downwards direction causes the inlet valve 59 to open and allow water to pass from the branch 63 to the branch 64, the overflow valve 58 being maintained in the closed position throughout the further downwards travel of the float 31, which progressively opens the inlet valve 59 relatively to its seat 61.

I may arrange for a small travel of the float during which both the overflow valve 58 and the inlet valve 59 are closed in order to permit small fluctuations in the quantity of water in the condenser well without any pumping action taking place.

It will be seen that, whenever a condenser well reaches a predetermined level at which the float opens the overflow valve, the extraction pump associated with that condenser well can discharge water through the overflow valve into a pipe line which is connected to the several branches 63 on the respective closed feed controllers on the other condensers.

If any condenser has a low water level compared with the predetermined overflow level, the inlet valve on that condenser will be open and water can pass into that condenser until the surplus water from the condenser which is on overflow has been transferred.

It will be seen that any surplus water in a condenser above the predetermined overflow level is transferred to one or other of the condensers in which the water level is below the predetermined overflow level. In the event of all the condensers in operation being full of water to the overflow level, the surplus water is transferred through a spring-loaded valve to the reserve feed tank, as explained in relation to Fig. 2.

Fig. 4 is a diagram illustrating the parallel operation of the closed feed system units. For the sake of simplification, two condensing systems only are illustrated. The line Y—E shows the discharge pressure capacity characteristic of a condensate pump Y. The line X—F shows the corresponding characteristic of a condensate pump X which is operating on the second condenser, the difference in characteristics being due to difference of vacua in the two condensers, or difference in operating speeds of the two condensate pumps, or differences in the manufacture of the impellers of the two pumps. The combined characteristic of the two pumps X and Y is shown by the curve X—G—H. When the two pumps X and Y are operating in parallel, there will be a frictional drop between each pump and the common point of discharge, such frictional

resistance being proportional to the square of the quantity of water flowing between the pump and the common point of discharge. At the combined discharge, the discharge pressure of both pumps is the same for both pumps, but the quantities of water discharged by the two pumps are different because of the different characteristics of the two pumps. Assume that the common discharge pressure is M, then the quantity of water discharged by the pump X is JL while LM is the quantity discharged by the pump Y and is equal to JK. If the two condensers are on equal loads, the condenser associated with the pump Y will fill up until the overflow valve is opened and pump Y discharges some of the condensate into the other condenser whence the pump X delivers it to the boilers. The quantity of condensate formed in the condenser with the pump Y is JK, which is equal to LM in the combined characteristic, and, of this quantity, MN is discharged to the system by the pump Y, while LN is discharged through the overflow valve where LN is equal to KL, and is subsequently discharged by the pump X to the system where JK is also equal to the condensate formed in the condenser with the pump X. If the other condenser is also full to overflow level, the quantity LN will be discharged to the reserve feed tank. This transfer of water will take place continually and adjust automatically at all times any differences between the condenser vacua, pump characteristics and any factors which affect the pump characteristics.

It will be appreciated that all the water required by the boilers during any fluctuations of load between full power and no load is available in the wells in the bases of the condensers, and no external source of water need be provided.

Since the whole of the working fluid is within the main circuit or sub-circuits connected to the main circuit, contamination from the atmosphere is prevented, and any deleterious gases which may enter the system in such parts of the system where a vacuum exists are removed by the vacuum-producing apparatus of the condensers, the condensers being designed to give the maximum deaerating effect so that the water dis-

charged from the condensers into the feed circuit is at the maximum possible temperature with the consequent optimum thermal efficiency and is free from any gases which might have corrosive effects on the parts of the steam power plant.

With a plurality of condensers in operation, any maldistribution of water between the condensers due to variations in loads is automatically adjusted by the operation of the closed feed controllers associated with the condensers.

What is claimed is:

1. A closed feed system for steam power plants operating in parallel, including at least two condensers having wells in their bases, condensate extraction pumps connected to said wells, water level controllers associated with said condenser wells and each comprising an overflow valve, an inlet valve and a float operative on change in water level in the respective condenser well to open the overflow valve when the water level in said well rises above a predetermined level and to open the inlet valve when the water level falls below a predetermined level, piping connecting said valves and extraction pumps whereby condensate passing from one condenser through the overflow valve of the respective condenser when open may pass through an inlet valve which may be open of another condenser, a reserve feed tank, a connection between said piping and said feed tank whereby condensate which passes through the overflow valve of one condenser when the inlet valve of no other condenser is open may pass to said reserve feed tank, and a spring-loaded valve intercalated in said connection.
2. A closed feed system for steam power plants as claimed in claim 1, including an evaporator intercalated in the system to make up water losses from the system and connections including said spring-loaded valve for leading to the reserve feed tank distilled water from the evaporator in excess of requirements.
3. A closed feed system for steam power plants as claimed in claim 1, including a connection provided with a float-operated valve between the reserve feed tank and one of the condensers.

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