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FORCED-FLOW STEAM GENERATORS

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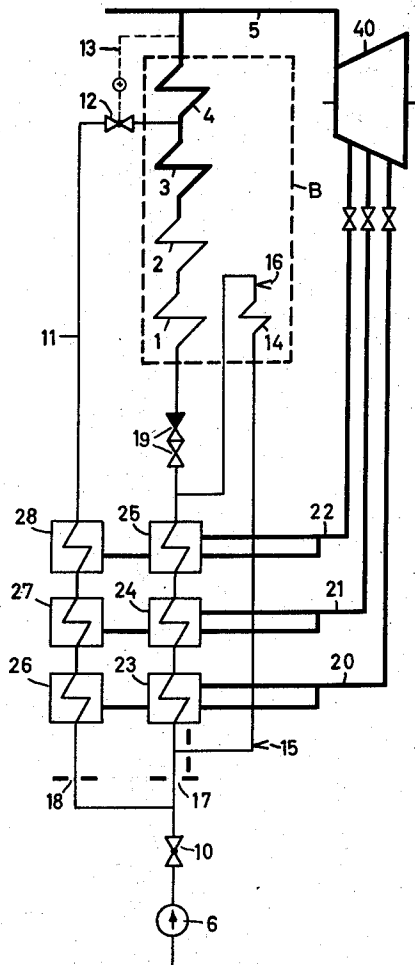


Fig. 2

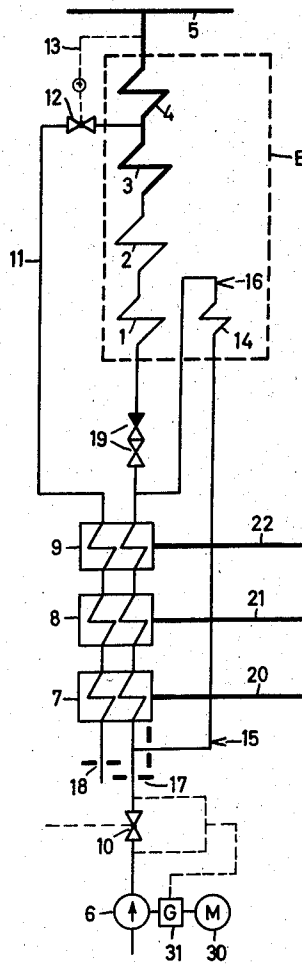


Fig. 1

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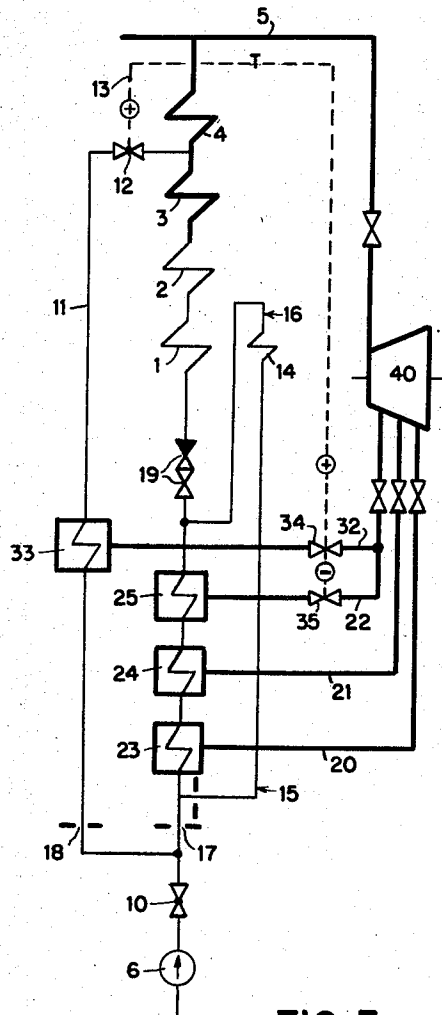
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FORCED-FLOW STEAM GENERATORS

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7 Claims. (Cl. 122—1)

My invention relates to forced-flow steam generators of the "once-through" type wherein the feed water is heated, evaporated and superheated in one passage through the tube system of the boiler which does not include any accumulator drums, all heating surfaces consisting entirely of tubes.

Such generators require, to a much greater extent than drum-type boilers, a most rapid adaptation of the delivered output to any variations in loading, such as a variation in the mechanical load imposed upon the turbines operated from the generator plant. This makes it desirable to minimize the inevitable time delays, such as those occurring in the combustion and flue system of the boilers. It has therefore become customary to regulate the operation of forced-flow generators by simultaneous and interrelated control of fuel supply, combustion-air supply, and supplied quantity of feed water. A so-called "auxiliary heating surface" has been provided, comprising a boiler tube heated by flue gases and extending hydraulically in parallel to a water-carrying portion of the main tube-system of the boiler so as to be traversed by a branched-off quantity of water proportional to the total feed-water flow. The temperature change of the water in such an auxiliary heating surface rapidly responds to changes in heating conditions, and is available as a temperature reference for the above-mentioned regulation. In this manner, a satisfactory coarse control of the steam output temperature has been obtained. For fine regulation of the steam temperature, the forced-flow generators have also been provided with desuperheaters consisting of controlled spray nozzles that inject water into the superheater stage of the boiler ahead of the final superheater.

My invention, in a more specific aspect, relates particularly to the above-mentioned type of forced-flow generators with auxiliary heating surface and water injection, and has for its main object to improve the accuracy and rapidity of the regulating performance by making the auxiliary heating surface more sensitively responsive to variations in heating conditions and by reducing detrimental effects of the injected water upon the regulating performance.

These and other objects and advantages as well as the features of my invention, said features being set forth with particularity in the claims annexed hereto, will be apparent from, and will be set forth in, the following description in conjunction with the drawings in which Figs. 1, 2 and 3 show, by way of example, the schematic circuit diagrams of three different embodiments respectively of steam generators according to the invention.

In Fig. 1, the main components of the boiler B proper are denoted by 1, 2, 3, 4 and 14. These components, forming a system of boiler tubes, are exposed to, and heated in, the burner and flue chambers of the boiler. The feed water enters into the first evaporator portion 1 which is heated mainly by radiation from the burners (radiant evaporator), and thence into the second evaporator portion 2 (final evaporator) which is mainly

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heated by convection and from which the working medium issues as steam. The steam passes through the intermediate superheater 3, preferably located in the radiant zone of the combustion chamber, and thence through the final superheater 4 from which the superheated steam issues into the fresh-steam conduit 5 leading to the steam consuming load, such as the turbine 40 shown in Fig. 2.

The component 14 in Fig. 1 is the auxiliary heating surface serving to provide a sensitive temperature response for the above-mentioned regulating purposes and more fully described below.

The feed water, after passing through conventional preheaters (not shown) is forced through the tube system of the generator by a feed pump 6 and passes through a regulating valve 10 and several high-pressure preheaters of which only three are shown at 7, 8 and 9. The pump 6 is driven from a motor 30 through a transmission gearing 31 controlled in dependence upon the difference in the respective pressures ahead and arrear of the regulator 10.

The regulator 10, as well as the fuel supply to the burners, is controlled in dependence upon the temperature of the water in the auxiliary heating surface 14 in the known manner; and a fine regulation of the generator output temperature is effected, also in the manner known as such, by injecting water into the superheated steam. For this purpose, the illustrated plant has an injection-water line 11 by means of which water is injected between the two superheaters 3 and 4. The injection quantity is regulated by a temperature-responsive device 13 in dependence upon the outlet steam temperature of the final superheater.

The temperature measuring points of the auxiliary heating surface 14 are indicated at 15 and 16. Denoted by 17 and 18 are quantity-measuring diaphragm gauges for the feed water and the injection water respectively. When using a regulatable feed pump 6, the regulator valve 10 may be omitted and the pump regulated instead. However, the check valve and shut-off valve shown at 19 remain necessary.

The features according to my invention, by virtue of which the illustrated generator plant is a distinct improvement over those heretofore known, relate to the particular connection and operation of the auxiliary heating surface 14 and the injection-water line 11 and will be more fully described presently.

In the known forced-flow generators, the auxiliary heating surface has its water inlet branched-off from the feed-water main line at a location within the boiler proper and behind the high-pressure preheaters and the check and shut-off valve. As a rule, the auxiliary heating surface has been connected to the generator main circuit in immediate parallel relation to the first evaporator stage (corresponding to evaporator 1 in Fig. 1). Similarly, the inlet point of the injection-water line was branched-off from the feed water main line at a point behind the high-pressure preheaters and behind the check and shut-off valve.

In contrast, the auxiliary heating surface 14 in the generator according to the invention has its water inlet branched-off outside of the boiler at a point ahead of the control and check valve 19 and ahead of one or more of the high-pressure superheaters. The water-outlet point of the auxiliary heating surface may be located between the evaporators 1 and 2 as in the known generators, but according to another, preferred feature of the invention, this point is located between the high-pressure preheaters and the first evaporator 1, preferably so that the auxiliary heating surface 14 lies hydraulically parallel to a group of consecutive preheaters as shown.

Also contrary to past practice, the injection-water

line 11 branches off the feed-water main line ahead of a high-pressure preheater, preferably at about the same pressure and temperature locality as the auxiliary heating surface; and the branched-off injection water, after passing through the quantity-measuring location at 18, is preheated by regenerative steam. In the embodiment of Fig. 1, the regenerative preheating is effected by passing the injection water, separate from the main flow of feed water, through all or some of the high-pressure preheaters. The regenerative-steam lines 20, 21, 22 of the respective preheaters 7, 8, 9 may be connected to respectively different steam outlets of the turbine as shown in Fig. 2.

The improvement afforded by the above-mentioned features will be understood from the following. Assume that temperature of the water passing through the auxiliary heating surface is increased 100° C., and that the temperature difference measured between the points 15 and 16 is 2° C. Then the temperature gauge connected between points 15 and 16 and providing a signal for regulation of the generator responds to a temperature change of 2%. Now consider the case where the water enters into the auxiliary heating surface 14 at such a high temperature that the water temperature increases only 50° C. This does not change the temperature tap-off of 2° C. Consequently, the temperature gauge now responds to 4% of the increase. Hence, the measuring sensitivity is reduced to one-half. Now, in generator development, there is the tendency to prefer highest feasible pressures and temperatures. Increase in pressure and temperature, however, results in corresponding increase of the preheating temperature in the regenerative stages of the plant. Consequently, if the auxiliary heating surface, in accordance with past practice, is branched off behind the last high-pressure regenerative stage, the water enters into the auxiliary surface at a correspondingly high temperature with the result of decreasing the additional heating of the water in the auxiliary heating surface and thus also decreasing the measuring and regulating sensitivity. However, if according to the invention the tap-off point of the auxiliary heating surface is located ahead of a high-pressure stage of the regenerative process, preferably ahead of the last, lowest-pressure stage, then the water enters into the auxiliary heating surface at a lower temperature and thus is subjected to a higher degree of heating resulting in increased measuring sensitivity.

Furthermore, the water-inlet point of the auxiliary heating surface is now located at a point where the temperature is approximately constant or varies only to a slight extent. This not only makes the temperature measurement more definite but also improves the accuracy of the quantity measurements at the diaphragm gauges 17 and 18. This is so because the water temperature at the measuring location is now virtually constant so that the specific volume and gravity of the water remain essentially uniform under all load conditions.

Since the injection water line 11 is branched-off at about the same location as the auxiliary heating surface, the just-mentioned advantage of improved accuracy of quantity measurement also applies to the injection water line.

In such a system, however, the quantity of water injected into the superheated steam may detrimentally affect the accuracy of temperature measurement at the auxiliary heating surface. However, as described, the injection water, after performing the quantity measurement at the diaphragm location 18, is preheated by regenerative steam with the effect of eliminating or greatly minimizing such detriments.

Instead of regeneratively heating the injection water in the main high-pressure preheaters as shown in Fig. 1, the heating of the injection water may also be effected in separate high-pressure preheaters connected hydraulically

parallel to the main preheaters. It is particularly advantageous to heat the injection water by means of a single additional high-pressure preheater which is connected to the uppermost, highest-pressure stage of the turbine. Since the quantity of water required for the auxiliary heating surface amounts to only about one-tenth of the injection water, the passing of the injection water through such a separate high-pressure preheater does not cause appreciable loss. Embodiments of the just-mentioned modifications will be described presently with reference to Figs. 2 and 3.

The plant illustrated in Fig. 2 is largely similar to that of Fig. 1, the same reference numerals being used in both illustrations for respectively corresponding components. According to Fig. 2, however, the injection water, after passing by the quantity-measuring gauge 18, is preheated in separate high-pressure preheaters. The feed water for the boiler passes through the main preheaters 23, 24, 25. The injection water in line 11 passes through the separate high-pressure preheaters 26, 27, 28. The preheaters 26, 27, 28 are supplied with regenerative steam from the turbine 40 through bleeder lines 20, 21, 22 in parallel relation to the main preheaters.

The embodiment in Fig. 3 is similar to those described above, the same reference characters being used for corresponding components respectively. According to Fig. 3, the injection water in line 11 is preheated in a single separate high-pressure preheater 33 which receives regenerative steam from the highest-pressure bleeder tap 32 of the turbine 40. The heating of the injection-water preheater 33 and of the feed-water preheater 25 with bleeder steam is controlled in response to a temperature signal at 13 and in correlation to the valve 12 in such a manner that the valve 35 in bleeder line 22 closes when the valves 12 and 34 open, and vice versa.

The above-mentioned measuring gauges or diaphragms 17 and 18, as well as the regulating accessories not essential to the invention proper, are well known and available as standardized equipment, and for that reason are not further described herein.

It will be obvious to those skilled in the art, upon study of this disclosure, that my invention permits of various modifications and may be embodied in designs other than those particularly illustrated and described herein, without departing from the essential features of my invention and within the scope of the claims annexed hereto.

I claim:

1. A forced-flow steam generator, comprising a generator main circuit having feed water supply means, high-pressure preheater means connected to said supply means, a boiler having an evaporator stage serially connected with said preheater means and a superheater stage serially connected with said evaporator stage; an auxiliary heating surface for temperature responsive regulation located in said boiler to be heated jointly with said evaporator and superheater stages, said auxiliary heating surface having a water inlet branched off said main circuit at a point ahead of said high-pressure preheater means and extending hydraulically parallel to a water-carrying portion of said main circuit; a water injection line branched off said main circuit ahead of said preheater means and having an injection point in said superheater stage, said injection line having a water-quantity measuring point near the branch-off location; and regenerative-steam heating means in heat-exchanging relation with said injection line between said measuring point and said injection point for preheating the injection water.

2. A forced-flow steam generator, comprising a generator main circuit having feed water supply means, high-pressure preheater means connected to said supply means, a boiler having an evaporator stage connected to said preheater means and a superheater stage connected to said evaporator stage; an auxiliary heating surface for temperature responsive regulation located in said boiler to be heated jointly with said evaporator and superheater stages, said auxiliary heating surface having a water inlet

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branched off said main circuit at a point ahead of said high-pressure preheater means and extending hydraulically parallel to a water-carrying portion of said main circuit; a water injection line branched off said main circuit ahead of said preheater means and having an injection point in said superheater stage, said injection line having a water-quantity measuring point near the branch-off location and extending through said high-pressure preheater means between said measuring point and said injection point for preheating the injection water.

3. A forced-flow steam generator plant having a fresh-steam line and bleeder lines and comprising a generator main circuit having feed water supply means, high-pressure preheater means connected to said supply means, a boiler having an evaporator stage connected to said preheater means and a superheater stage connected between said evaporator stage and said fresh-steam line; said preheater means having several consecutive units in said respective bleeder lines for regenerative heating; an auxiliary heating surface for temperature responsive regulation located in said boiler to be heated jointly with said evaporator and superheater stages, said auxiliary heating surface having a water inlet branched off said main circuit at a point ahead of said high-pressure preheater means and extending parallel to a water-carrying portion of said main circuit; a water injection line branched off said main circuit ahead of said preheater means and having an injection point in said superheater stage, said injection line having a water-quantity measuring point near the branch-off location and extending, between said measuring point and said injection point, through said preheater means for regeneratively heating the injection water.

4. A forced-flow steam generator plant having a fresh-steam line and bleeder lines and comprising a generator main circuit having feed water supply means, high-pressure preheater means connected to said supply means, a boiler having an evaporator stage connected to said preheater means and a superheater stage connected between said evaporator stage and said fresh-steam line; said preheater means having several consecutive units in said respective bleeder lines for regenerative heating; an auxiliary heating surface for temperature responsive regulation located in said boiler to be heated jointly with said evaporator and superheater stages, said auxiliary heating surface having a water inlet branched off said main circuit at a point ahead of said high-pressure preheater means and extending hydraulically parallel to a water-carrying portion of said main circuit; a water injection line branched off said main circuit ahead of said preheater means and having an injection point in said superheater stage, said injection line having a water-quantity measuring point near the branch-off location; and further regenerative preheater units connected to said respective bleeder lines, said injection line extending, between said measuring point and said injection point, serially through said further units for heating the injection water.

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5. A forced-flow steam generator plant having a fresh-steam line and bleeder lines, and comprising a generator main circuit having feed water supply means, high-pressure preheater means connected to said supply means, a boiler having an evaporator stage connected to said preheater means and a superheater stage connected between said evaporator stage and said fresh-steam line; said preheater means having several consecutive units in said respective bleeder lines for regenerative heating; an auxiliary heating surface for temperature responsive regulation located in said boiler to be heated jointly with said evaporator and superheater stages, said auxiliary heating surface having a water inlet branched off said main circuit at a point ahead of said high-pressure preheater means and extending hydraulically parallel to a water-carrying portion of said main circuit; a water injection line branched off said main circuit ahead of said preheater means and having an injection point in said superheater stage, said injection line having a water-quantity measuring point near the branch-off location; and a separate high-pressure preheater connected to the one bleeder line of highest pressure and in heat-exchanging relation with said injection line between said measuring point and said injection point.

6. A forced-flow steam generator plant having a fresh-steam line and bleeder lines, and comprising a generator main circuit having feed water supply means, high-pressure preheater means connected to said supply means, a boiler having an evaporator stage connected to said preheater means and a superheater stage connected between said evaporator stage and said fresh-steam line; said preheater means having several consecutive units in said respective bleeder lines for regenerative heating; an auxiliary heating surface for temperature-responsive regulation located in said boiler, said auxiliary heating surface having a water inlet connected to said main circuit ahead of said preheater units and having a water outlet connected to said main circuit between said evaporator stage and said preheater means; and a water injection line branched off said main circuit ahead of said preheater means and having an injection point in said superheater stage.

7. A forced-flow steam generator plant according to claim 6, comprising check and control valve means in said main circuit between said evaporator stage and said preheater means, said water outlet of said auxiliary heating surface being at a point between said valve and said preheater means.

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