

July 11, 1961

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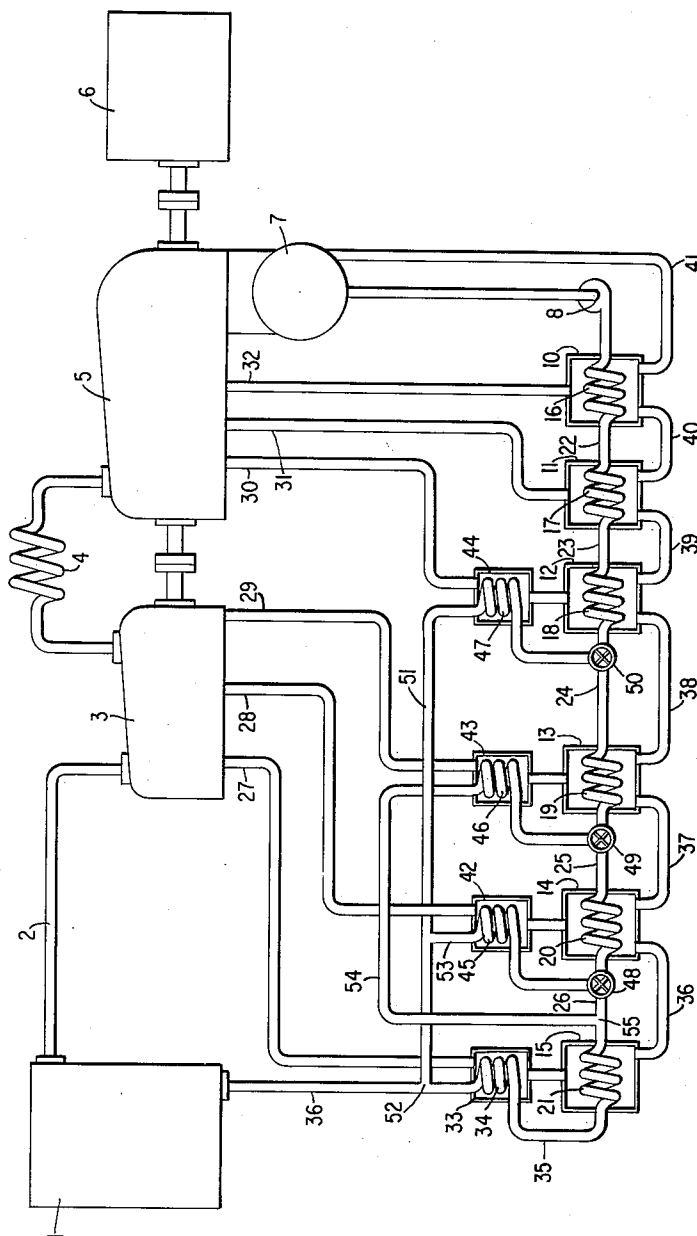
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DESUPERHEATER ARRANGEMENTS FOR STEAM TURBINES

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FIG. 1



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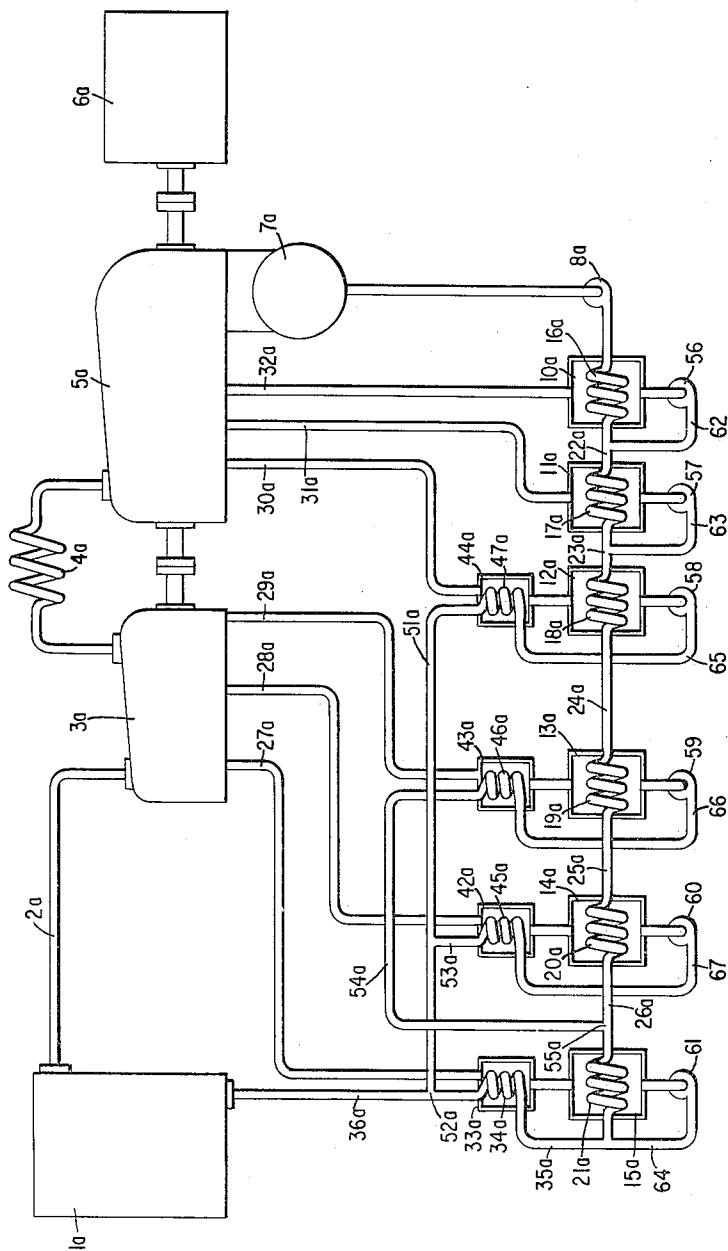
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DESUPERHEATER ARRANGEMENTS FOR STEAM TURBINES

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FIG. 2



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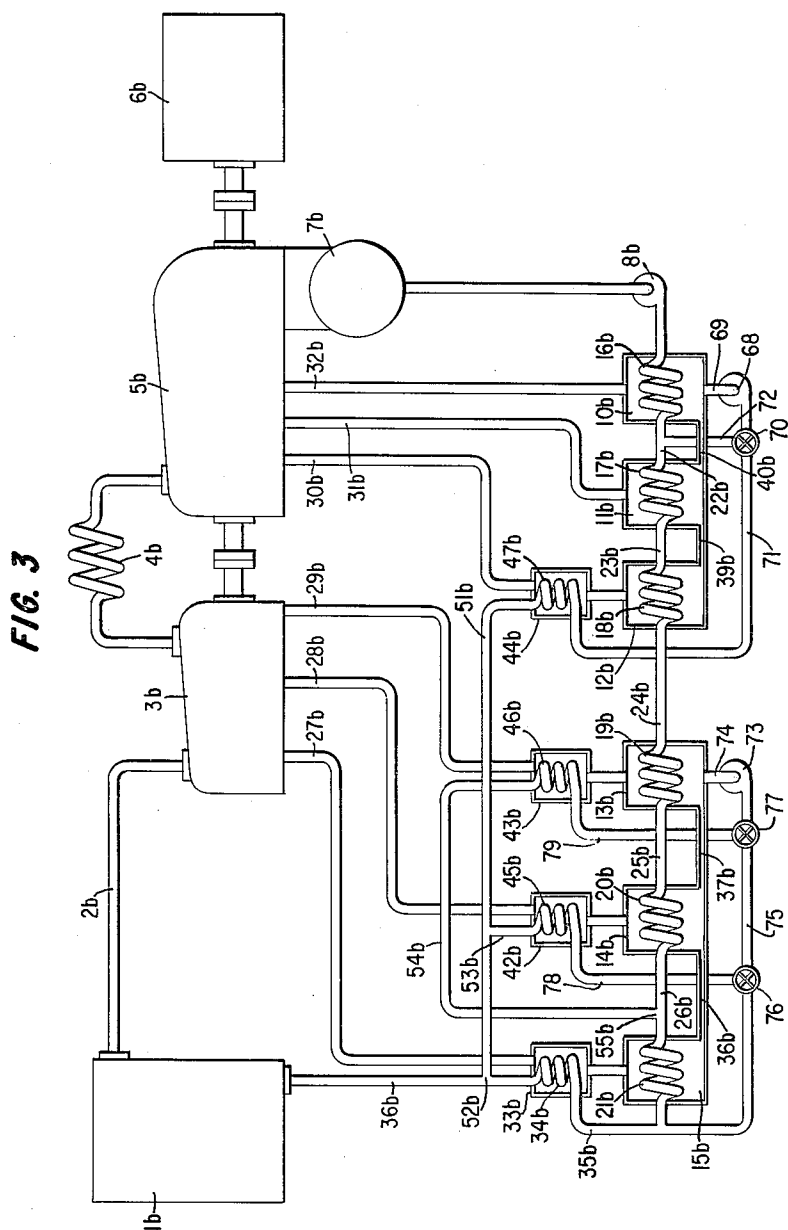
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2,991,620 DESUPERHEATER ARRANGEMENTS FOR STEAM TURBINES

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The present invention relates to steam turbines in which feed water is heated by superheated extracted or tapped steam, and this application is a continuation-in-part of my co-pending application Serial No. 636,084, filed January 24, 1957, now abandoned.

It is known that the increase in the thermal efficiency of a steam cycle achieved by regeneration is enhanced by improvement in the utilization of the superheat of the tapped steam for heating the feed water. Heat contained in the superheated steam has to be transferred to the feed water with the smallest possible temperature difference between the cooled superheated steam and the heated feed water, in order to reduce to a minimum the increase of entropy in the desuperheaters.

If the amount of superheated steam tapped for regeneration is G_s (lb./hr.), its outlet temperature from the turbine is t_s °F., its condensation temperature at the extraction pressure is t_{sk} °F., and its specific heat is c_s (the mean specific heat between the temperatures t_s and t_{sk}), then its superheating heat surrendered to the feed water is expressed as:

$$G_s \cdot c_s (t_s - t_{sk})$$

It is known that, in special desuperheaters which are separated from the usual feed water condensation heaters in which the tapped steam condensates, a certain amount of feed water G_w (lb./hr.) may be heated from a temperature of t_{w1} to a temperature t_{w2} with the result that the feed water receives in the desuperheater the heat

$$G_w \cdot c_w (t_{w2} - t_{w1})$$

If the maximum effect of the desuperheater is to be achieved, it is necessary that the tapped steam should surrender to the feed water in the first place its entire superheat according to the equation

$$G_s \cdot c_s (t_s - t_{sk}) = G_w \cdot c_w (t_{w2} - t_{w1}) \quad (I)$$

wherein the following condition must be fulfilled

$$t_s > t_{w2}, \quad t_{sk} > t_{w1}$$

(in a countercurrent desuperheater).

The optimum effect of the desuperheater is achieved only when the following conditions are also simultaneously fulfilled:

The final temperature difference in the desuperheater

$$t_s - t_{w2} = \Delta t_2$$

has to be as small as possible (for example, about 10° F.); and

The initial temperature difference in the desuperheater

$$t_{sk} - t_{w1} = \Delta t_1$$

has also to be as small as possible (for example, about 10° F.). This requirement means that feed water of a temperature lower by Δt_1 than the condensation temperature of the cooled steam at the extraction pressure has to enter the desuperheater.

The simultaneous fulfillment of both the above mentioned conditions in Equation I is possible only when

$$t_s - t_{sk} = t_{w2} - t_{w1}$$

and therefore also

$$G_s \cdot c_s = G_w \cdot c_w$$

or

$$G_w = G_s \frac{c_s}{c_w}$$

The optimum amount of water entering the desuperheater with a temperature $t_{w1} = t_{sk} - \Delta t_1$ is therefore determined by this condition and is always substantially lower than the total amount of the feed water flowing through the regeneration system and rather close to the extracted amount of steam G_s in the respective tap. Roughly, it may even be assumed that $G_w = G_s$.

The feed water in an amount of G_w heated in the desuperheater to a temperature $t_{w2} = t_s - \Delta t_2$ has to be added to the remaining feed water at that point where the temperature of the remaining feed water is nearest to the temperature t_{w2} , as otherwise the thermodynamic advantages of the desuperheater would not be effective. If the temperature t_{w2} (when the tapped steam is superheated to a small degree only) were lower than the condensation temperature t_{sk}' of the steam in the regeneration tap of the next higher pressure, the desuperheater would be of no practical value. If the temperature t_{w2} is higher than the temperature of the feed water leaving the regeneration system, the amount G_w is not added until behind the last condensation heater.

None of the known desuperheater arrangements are capable of achieving the above quoted conditions for its best operation while retaining the desired simplicity of the arrangement.

It is an object of the present invention to provide a desuperheater arrangement having a maximum efficiency while employing a minimum number of desuperheaters. According to the invention the number of desuperheaters does not exceed the number of taps for the superheated steam. The desuperheaters can be relatively small since only small quantities of water are passed therethrough and high flow velocities may be obtained in the desuperheaters so as to increase the rate of heat transfer and permit further reductions in the dimensions of the desuperheaters, particularly in the application of the invention to high pressure tappings and desuperheaters.

According to the invention, the superheated steam in the desuperheater for tapped steam in the regeneration system of a steam turbine is cooled down in the desuperheater by a flow of feed water with an admission temperature equal to, or lower than, the condensation temperature of the cooled steam, such flow of feed water being reduced so that the initial and final temperature drops in the desuperheater are as small as possible in order to obtain a maximum increase of water temperature in the desuperheater. Further, the water heated in the desuperheater is added to the remaining feed water at a point, where the temperature of the remaining feed water is as close as possible to that of the feed water heated in the desuperheater.

The above, and other objects, features and advantages of the invention will be apparent in the following detailed description of illustrative embodiments thereof which is to be read in connection with the accompanying drawings, wherein:

FIG. 1 is a schematic view of an arrangement of desuperheaters embodying this invention;

FIG. 2 is a similar schematic view showing another embodiment of the invention; and

FIG. 3 is a schematic view of still another embodiment of the invention.

Referring to FIG. 1, it will be seen that, in the system there illustrated, a steam generator or boiler 1 is connected to a conduit 2 through which highly superheated steam is supplied to a high pressure part 3 of a steam turbine. From the part 3 of the turbine, steam flows through a re-

superheater 4 to the low pressure part 5 of the steam turbine which may be used to drive an electric generator 6. A condenser 7 is connected to the low pressure part of the turbine, and the condensate therefrom is fed by a pump 8 through a succession of condensation feed water heaters 10, 11, 12, 13, 14 and 15 having their internal coils 16, 17, 18, 19, 20 and 21 respectively, connected in series by conduits 22, 23, 24, 25 and 26 to receive the condensate from the pump 8.

Conduits 27, 28 and 29 extend from the high pressure part 3 of the turbine and conduits 30, 31 and 32 extend from the low pressure part 5 of the turbine for tapping or extracting superheated steam from the turbine at locations where the steam is at progressively decreasing pressures.

As in existing systems, a desuperheater 33, which receives superheated steam from the tapping conduit 27 at the highest pressure, has a coil 34 connected, at one end, to a conduit 35 extending from the coil 21 of feed water heater 15 to receive all of the water from the latter and to return such heated water to the boiler or steam generator 1 by way of a conduit 36.

The illustrated system further has a known arrangement for passing the condensate from the tapped or extracted superheated steam in cascades through the feed water heaters. Such known arrangement may include a conduit 36 extending from feed water heater 15 to feed water heater 14, a conduit 37 extending from feed water heater 14 to feed water heater 13, a conduit 38 extending from feed water heater 13 to feed water heater 12, a conduit 39 extending from feed water heater 12 to feed water heater 11, a conduit 40 extending from feed water heater 11 to feed water heater 10, and a conduit 41 extending from feed water heater 10 to condenser 7 where the condensed extracted steam is added to the condensate to be passed through the coils of the feed water heaters by pump 8.

Since the steam extracted from the turbine by the conduit 32 at the location of lowest pressure is assumed to be wet steam, the conduit 32 is connected directly to the corresponding feed water heater 10 in the known manner. Similarly, it may be safely assumed that the steam extracted or tapped through the conduit 31 at the location of next higher pressure is only slightly superheated, if at all, so that, in accordance with the invention, the conduit 31 may also be connected directly to the associated feed water heater 11, as shown.

However, assuming that the steam tapped from the turbine through the conduits 28, 29 and 30 is highly superheated, it will be seen that, in accordance with the invention, desuperheaters 42, 43 and 44 are connected to the conduits 28, 29 and 30 and to the associated feed water heaters 14, 13 and 12, respectively, so that the tapped superheated steam passes through a desuperheater before entering a feed water heater. Further, it will be seen that the desuperheaters 42, 43 and 44 contain coils 45, 46 and 47, respectively, through which a portion of the feed water may pass in heat transfer relationship with the superheated steam. The coils 45, 46 and 47 are connected to the conduits 26, 25 and 24, respectively, at valves or flow control members 48, 49 and 50 which are interposed in said conduits to regulate the portion of the heated feed water supplied from the conduits 26, 25 and 24 to the coils of the desuperheaters 42, 43 and 44, respectively. Since the valve 50 is placed in conduit 24 just at the outlet for the feed water from the condensation heater 12, the water temperature at the inlet of coil 47 is just lower by the amount Δt than the condensation temperature of the steam extracted through conduit 30 and condensing in heater 12 after being precooled in desuperheater 33. As the temperature of the steam extracted through conduit 30 is assumed to be higher than the condensation temperature of the high pressure steam extracted through conduit 27 and condensing in the condensation heater 15, the feed water from coil 47 of desuperheater

44 must, in this case, be added to the other feed water by way of a conduit 51 which connects to the conduit 36 at the point 52, that is, in the feed water conduit connected to the outlet from the whole regeneration system in advance of the boiler 1. The same applies also to the desuperheater 42 according to the invention and, therefore, the feed water leaving the coil 45 of this desuperheater is also added to the other feed water at the point 52 by means of a conduit 53 connected to conduit 51 extending from the coil of desuperheater 44.

On the other hand, assuming that the temperature of the steam tapped through conduit 29 is lower than the condensation temperature of the steam tapped through conduit 27 and condensing in the heater 15, but higher than the condensation temperature of the steam tapped through 28 and condensing in the heater 14, then the discharge of feed water from the coil 46 of desuperheater 43 is, according to the invention, mixed with the other feed water by means of a conduit 54 connected to the conduit 26 at a point 55 situated between the heater 15 and the valve 48. The feed water admitted to coil 46 is, in accordance with the foregoing, separated from the other feed water by the valve 49 at the outlet from the coil 19 of heater 13, but the principle of the invention would remain the same if the water admitted to coil 46 was separated from the other feed water at a point in conduit 24 where the temperature of the feed water is also lower than the condensation temperature of the steam extracted through conduit 29 and condensing in the heater 13.

Referring now to FIG. 2 of the drawings, it will be seen that the system embodying the present invention is generally similar to that illustrated in FIG. 1, and that the parts of the system in FIG. 2 are identified by the same reference numerals employed in connection with the corresponding parts of the system described in connection with FIG. 1, but with the letter "a" appended thereto. Thus, the system of FIG. 2 includes condensation feed water heaters 10a, 11a, 12a, 13a, 14a and 15a associated with the conduits 32a, 31a, 30a, 29a, 28a and 27a, respectively, through which steam is extracted or tapped from the turbine. As in the first described embodiment of the invention, the conduits 32a and 31a, which extend from locations of relatively low pressure are connected directly to the associated condensation feed water heaters 10a and 11a, whereas the conduits 30a, 29a, 28a and 27a, which are connected to locations of relatively high pressure and extract superheated steam, are connected to associated desuperheaters 44a, 43a, 42a and 33a, respectively.

The coils of the condensation feed water heaters are connected in series by conduits 22a, 23a, 24a, 25a and 26a so that the condensate from the usual condenser 7a is pumped successively through the coils of the feed water heaters by the pump 8a. All of the heated feed water from the coil 21a of condensation feed water heater 15a is led through conduit 35a to the coil 34a of desuperheater 33a where the feed water is further heated by heat transfer from the tapped steam led to the desuperheater 33a through the conduit 27a. All of the feed water is returned to the boiler or steam generator 1a by way of the conduit 36a.

The conduits 36, 37, 38, 39, 40 and 41 providing a cascade connection between the several condensation feed water heaters of the system illustrated in FIG. 1 are eliminated in the system of FIG. 2 as are the flow control members or valves 48, 49 and 50 of the first described embodiment. On the other hand, the system of FIG. 2 additionally includes pumps 56, 57, 58, 59, 60 and 61 having their inlets connected to the condensation feed water heaters 10a, 11a, 12a, 13a, 14a and 15a, respectively, to receive the condensate from the latter. The outlets or discharge sides of the pumps 56 and 57 are connected by conduits 62 and 63 to the conduits 22a and 23a, respectively, where the condensates from

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the feed water heaters 10a and 11a are mixed with the main flow of feed water. Similarly, the outlet or discharge side of the pump 61 receiving condensate from the feed water heater 15a is connected directly to the conduit 35a by way of a conduit 64.

In accordance with the present invention, the outlet or discharge sides of the pumps 58, 59 and 60 are connected, as by conduits 65, 66 and 67, respectively, to the coils 47a, 46a and 45a, respectively, of the desuperheaters 44a, 43a and 42a, so that the amounts of feed water heated in such desuperheaters are equal to the amounts of superheated steam extracted from the turbine through the related conduits 30a, 29a and 28a, respectively.

As in the first described embodiment of the invention, the temperature of the steam extracted through conduit 30a is assumed to be higher than the condensation temperature of the steam extracted through the conduit 27a and condensing in the feed water heater 15a, so that the feed water from coil 47a of desuperheater 44a is added to the other feed water by way of a conduit 51a which connects to the conduit 36a at the point 52a between the coil 34a of desuperheater 33a and the boiler 1a. Similarly, the heated feed water from coil 45a of desuperheater 42a is added to the feed water flowing through conduit 36a by way of a conduit 53a connected to the above mentioned conduit 51a.

On the other hand, it is also assumed in the system of FIG. 2 that the temperature of the steam tapped or extracted through the conduit 29a is lower than the condensation temperature of the steam tapped through the conduit 27a and condensing in the heater 15a, but higher than the condensation temperature of the steam tapped through conduit 28a, so that, in accordance with the present invention, the discharge of feed water from the coil 46a of desuperheater 43a is mixed with the other feed water by means of a conduit 54a connected to the conduit 26a at a point 55a situated between the coils of the condensation feed water heaters 14a and 15a.

With the system illustrated in FIG. 2, it is very easy to achieve an increase of pressure at the outlet or discharge sides of the pumps 58, 59 and 60 for effecting an increase in the flow velocity of the feed water through the coils 47a, 46a and 45a of the associated desuperheaters, thereby to permit a reduction in the dimensions of the latter while increasing the rate of heat transmission between the feed water and the superheated tapped steam fed to such desuperheaters.

Referring now to FIG. 3 of the drawings, it will be seen that the system there illustrated is generally similar to that described in connection with FIG. 1, and the parts of the system of FIG. 3 are identified by the same reference numerals annexed to the corresponding part of FIG. 1, but with the letter "b" appended thereto.

In the system of FIG. 3, the condensate from feed water heater 15b is fed to the feed water 14b by way of a conduit 36b, and the condensate from feed water heater 14b is fed to feed water heater 13b by way of a conduit 37b. Similarly, the condensate from feed water heater 12b is fed to feed water heater 11b by way of a conduit 39b, and the condensate from feed water heater 11b is fed to feed water heater 10b by way of a conduit 40b. Thus, the feed water heaters 10b, 11b and 12b, and the feed water heaters 13b, 14b and 15b are connected together in corresponding groups or cascades.

All of the condensate from the group of feed water heaters 10b, 11b and 12b is fed to the inlet of a feed pump 68 by way of a conduit 69 extending from feed water heater 10b, while the outlet or discharge side of the feed pump 68 is connected to a valve or flow control member 70 which determines the proportions of the condensate admitted to conduits 71 and 72 extending from such valve. The conduit 71 is connected to

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the coil 47b of desuperheater 44b, while the conduit 72 is connected to the conduit 22b between the coils 16b and 17b of the feed water heaters 10b and 11b.

Similarly, all of the condensate from the group of feed water heaters 13b, 14b and 15b is admitted to the inlet of a feed pump 73 by way of a conduit 74 extending from feed water heater 13b, while the discharge or outlet side of the pump 73 is connected to a conduit 75 which is joined to the conduit 35b extending from coil 21b of feed water heater 15b to coil 34b of desuperheater 33b. Two flow control valves 76 and 77 are interposed in the conduit 75 and control the proportion of the total condensate admitted from the conduit 75 to conduits 78 and 79, respectively, which are connected to the coils 45b and 46b of desuperheaters 42b and 43b, respectively.

It will be apparent that, with the system of FIG. 3, the valves 76 and 77, permit reduction of the amount of feed water fed through the coils of the associated desuperheaters 44b, 42b and 43b, respectively, while the pumps 68 and 73 make it easy to increase the flow velocity of the feed water through the desuperheaters 42b, 43b and 44b so that the dimensions of the latter may be decreased while increasing the rate of heat transmission between the feed water and the superheated steam admitted to such desuperheaters.

As in the embodiments of the invention illustrated in FIGS. 1 and 2, the heated feed water from the desuperheaters 42b and 44b is mixed with the other feed water at the point 52b in the conduit 36b, while the heated feed water from the desuperheater 43b is mixed with the other feed water by way of the conduit 54b connected to the conduit 26b at the point 55b between the coils of the feed water heaters 14b and 15b.

Although illustrative embodiments of the invention have been described in detail herein, it is to be understood that the invention is not limited to those precise embodiments, and that various changes and modifications may be effected therein without departing from the scope or spirit of the invention, except as defined in the appended claims.

What is claimed is:

1. In a regeneration system for a steam turbine having a steam generating boiler, a condenser receiving the exhausted steam from the turbine, a plurality of conduits extracting steam from the turbine at locations of different pressures defining a number of extraction stages of the turbine, and a plurality of feed water heaters defining the main feed water line connected in series to said condenser, each feed water heater being associated with one extraction stage of the turbine so as to condense the extracted steam from the conduit of the related extraction stage, while heating the condensate from said condenser, and means for adding the condensed extracted steam from said feed water heaters to the condensate of said condenser to make up together the feed water for the steam generating boiler; the combination of a plurality of desuperheaters each related to a respective extraction stage of the turbine and each having a steam path and a water path, the steam path of each desuperheater being interposed in the steam extraction conduit of the related extraction stage, and by-pass conduit means connecting the water paths of said desuperheaters with said main feed water line, the water path of each desuperheater receiving condensate through said by-pass conduit means from a location in the series of feed water heaters preceding the feed water heater related to the extraction stage of next higher pressure than the extraction stage related to said desuperheater, and the heated condensate from desuperheater being added, by way of said by-pass conduit means, to the main feed water line at a point following said feed water heater related to the next extraction stage.

2. In a regeneration system for a steam turbine having a steam generating boiler, a condenser receiving the exhausted steam from the turbine, a plurality of conduits

extracting superheated steam from the turbine at locations of different pressures, and a series of feed water heaters connected to said condenser and each associated with one of the superheated steam extracting conduits to condense the superheated steam extracted by the related conduit while heating the condensate from said condenser so that said condensate from the condenser and the condensed superheated steam together make up the feed water for the steam generating boiler; the combination of desuperheaters interposed in at least some of said superheated steam extracting conduits, means conducting through said desuperheaters only part of the condensate from said condenser flowing out of the related feed water heaters so that the superheated extracted steam passing through said desuperheaters is cooled in the latter by heat exchange with the portions of said feed water represented by said condensate conducted through the desuperheaters, and means adding said portions of the feed water to the remainder of the feed water at locations where the temperatures of the latter are as close as possible to the temperatures of said portions of the feed water following passage through said desuperheaters.

3. In a regeneration system for a steam turbine; the combination as in claim 2, wherein said means conducting through said desuperheaters only part of the condensate from said condenser includes flow control means interposed between the successive feed water heaters of said series, and a conduit extending from each flow control means to the related desuperheater, each of said flow control means being adjustable to determine the proportions of said condensate from the condenser passing through the flow control means to the next feed water heater of said series and to the related desuperheater.

4. In a regeneration system for a steam turbine having a steam generating boiler, a condenser receiving the exhausted steam from the turbine, a plurality of conduits extracting steam from the turbine at locations of different pressures defining a number of extraction stages of the turbine, and a series of feed water heaters defining the main feed water line connected to said condenser with each feed water heater being associated with one of the steam extracting conduits to condense the steam extracted by the related conduit while heating the condensate from said condenser so that said condensate from the condenser and the condensed extracted steam together make up the feed water for the steam generating boiler; the combination of desuperheaters for at least some of said steam extracting conduits, each of said desuperheaters having a steam path and a water path extending there-through, means conducting through said water path of each desuperheater the condensed extracted steam from the related feed water heater, said steam path of each desuperheater being interposed in the related steam extracting conduit so that superheated extracted steam passing through said desuperheater is cooled in the latter by heating the condensed extracted steam passing along the related water path, and means adding said heated condensed extracted steam from the water path of each desuperheater to the main feed water line at the location along the latter following the feed water heater related

to the extraction stage of the next higher pressure than is the extraction stage of said desuperheater.

5. In a regeneration system for a steam turbine; the combination as in claim 4, wherein said means conducting through said water path of each desuperheater the condensed extracted steam from the related feed water heater includes pump means increasing the velocity of flow of said condensed extracted steam through said water path of the desuperheater for permitting reduction in the dimensions of the latter by reason of the consequent high efficiency of heat transfer between the superheated extracted steam and the condensed extracted steam.

6. In a regeneration system for a steam turbine having a steam generating boiler, a condenser receiving the exhausted steam from the turbine, a plurality of conduits extracting superheated steam from the turbine at locations of different pressures, and a series of feed water heaters connected to said condenser and each associated with one of the steam extracting conduits to condense the steam extracted by the related conduit while heating the condensate from said condenser so that said condensate from the condenser and the condensed extracted steam together make up the feed water for the steam generating boiler; the combination of desuperheaters having steam paths interposed in at least some of said steam extracting conduits and water paths, means accumulating the condensed steam from groups of adjacent feed water heaters, means conducting through said water paths of the desuperheaters parts of said accumulated condensed superheated steam so that superheated extracted steam passing through said steam paths of the desuperheaters is cooled in the latter by heat exchange with said parts of the condensed superheated steam representing portions of the feed water for the boiler, and means adding said portions of the feed water to the remainder of the feed water at locations where the temperatures of the latter are as close as possible to the temperatures of said portions of the feed water following passage through said desuperheaters.

7. In a regeneration system for a steam turbine; the combination as in claim 6, wherein said means conducting through said water paths of the desuperheaters parts of said accumulated condensed superheated steam includes pump means receiving the accumulated condensed superheated means from each group of feed water heaters, conduit means for conducting the discharge from said pump means into the flow of condensate from said condenser passing through said feed water heaters and having flow control means interposed therein for each of said desuperheaters, and conduit means extending from each of said flow control means to the related desuperheater, each of said flow control means being operable to determine the proportions of said discharge from the pump means conducted through the related desuperheater and into said flow of condensate from said condenser, respectively.

References Cited in the file of this patent

UNITED STATES PATENTS

2,643,519 Powell ----- June 30, 1953